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Management and Costs of FIELD-SHELLING AND ARTIFICIAL DRYING OF CORN IN ILLINOIS

By V. W. Davis, R. N. Van Arsdall, and J. E. Wills

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Urbana, Illinois February, 1959

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Management and Costs of Field-Shelling and Artificial Drying of Corn in Illinois

By V. W. Davis, R. N. Van Arsdall,
and J. E. Wills[1]

Farmers have several choices in methods of harvesting corn. The most common method is to pick and husk with a mechanical picker and put the ears in a crib for natural drying. But now several Illinois farmers are harvesting with a field sheller, drying the shelled corn with a heated-air drier, and storing it in bins.

Field-shelling equipment was introduced about 20 years ago, but its development was retarded by problems of storage of shelled corn. Unless field-shelled corn is artificially dried, its moisture content is usually too high for safe storage on the farm or for sale without a discount in price.[2] The manufacture of heated-air drying units that can be used on the farm now make it possible to pick and shell corn early and dry it artificially before storage or sale.

For several reasons, Illinois farmers are interested in a new method of harvesting corn. Their ear-corn storage structures are either inadequate for present production or they are in poor condition. Replacement with shelled-corn storage provides opportunities to build relatively low-cost structures and to reduce storage losses. Harvesting early at a high-moisture content is one way of reducing field losses. In some years, early picking and artificial drying will permit farmers to avoid severe losses of corn from late season storms. Furthermore, shelled corn is easier to handle than ear corn, and field-shelling eliminates shelling from the crib and disposing of the cobs.

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[1] V. W. Davis and R. N. Van Arsdall, Agricultural Economists, Agricultural Research Service, U. S. Department of Agriculture, and Collaborators, Illinois Agricultural Experiment Station; and J. E. Wills, Professor of Farm Management, University of Illinois.

[2] Excessive moisture for storage of shelled corn is considered to be any moisture level above 13 percent. For detailed information, see "Storage of Small Grains and Shelled Corn on the Farm" by C. K. Shedd and R. T. Cotton, U. S. Dept. Agr. Farmers' Bul. 2009, p. 3, 1949. Excessive moisture for marketed corn is above 15.5 percent. Premiums are not normally paid for corn below this content except through higher basic bids. Market discounts in common use in Illinois in 1954 and 1955 were 3 cents a bushel for each percent moisture from 15.6 to 20.0 percent, and 4 cents a bushel for each percent above 20.1 percent.

PURPOSE OF STUDY

This bulletin presents an economic analysis of the experience of 77 Illinois farmers who field-shelled, dried the shelled corn with heated-air driers, and stored it in bins. Its purpose is to indicate the most economical and practical combinations of equipment and structures, together with the operating methods for effective performance of the various jobs in the harvesting process. The specific objectives of the study were as follows:

1. To ascertain the size, type, tenure, system of farming, and equipment and storage structures for corn on farms whose operators have adopted the field-sheller and heated-air-drier method of harvesting corn.
2. To identify the chief management problems involved in field-shelling, drying, and storage of shelled corn.
3. To develop standards of labor and equipment use and costs of typical systems of field-shelling, drying, and storage of corn.
4. To analyze the costs of different systems of harvesting for various quantities of corn.

In addition, consideration has been given (1) to managerial problems and costs of storing high-moisture corn for feed in airtight bins instead of drying and storing in conventional cribs; and (2) to the implications of field-shelling and artificial drying on the marketing of corn.

METHOD OF STUDY

The names of about 200 farmers in the major corn-producing areas in central and northern Illinois who had field shellers and driers in 1954 were obtained from farm advisers, Farm Bureau Farm Management Service fieldmen, machinery dealers, and public service companies. The list included nearly all eligible farmers.

Seventy-seven farmers who represented the use of various types of shelling and drying equipment were interviewed before the 1954 corn-harvesting season. Information was recorded as to the size, type, and tenure of the farms; the labor force; systems of farming; and corn-harvesting equipment and storage structures.

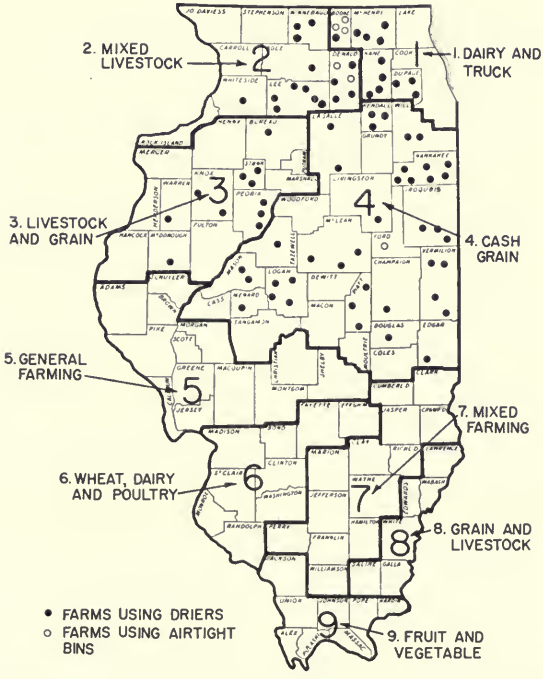
At that time, arrangements were made with each farmer to keep a daily record of man-hours, machine-hours, and other operating costs of field-shelling, drying, and storing their corn for the 1954 season. Forty-five farmers completed their records. After harvest, 62 of the 77 farmers were visited a second time to obtain additional information

about their harvesting operations. Time and travel studies were made on 23 of the farms. Field losses of ear and shelled corn were measured on 32 of the farms visited during the harvesting season.

Additional data on corn storage and marketing were obtained by a questionnaire mailed to a selected list of cooperators in August, 1955. A final follow-up field schedule was completed on a selected list of 19 cooperators after the 1955 harvest season.

LOCATION AND CHARACTERISTICS OF FARMS

The farms studied were located in central and northern Illinois (Fig. 1), averaged 393 tillable acres and 184 acres of corn, and were about equally divided between grain and livestock farms. Fifty-one percent were cash-grain farms; the remaining 49 percent were livestock farms. Most of the livestock farms were either combination beef cattle and hog farms or specialized beef cattle or hog farms. These farms were operated under all systems of tenure, with tenant operators repre-



Location of 77 Illinois farms using driers and 6 farms using airtight bins, 1954. (Fig. 1)

senting 36 percent; owner-operators, 33 percent; part-owners, 27 percent; and manager-operators, 4 percent of all farms.[1]

Corn was the chief crop produced on the survey farms. The crops produced, in percentage of tillable acres, were as follows: corn, 47 percent; hay and pasture, 17 percent; oats, 16 percent; soybeans, 14 percent; wheat, 4 percent; and other crops, 2 percent. Of the corn produced in 1954, 39 percent was fed to livestock.[2]

An average of 28 months of labor per year was used on each farm. Operator labor accounted for 12 months and family labor for 5 months. Hired labor amounted to 11 months, or 40 percent of the total. Seventy percent of the farms used some hired labor.

HARVESTING AND HANDLING MACHINES AND EQUIPMENT

Field Shellers

The two basic types of field shellers used were the picker-sheller and the picker and sheller. The picker-sheller was used on 54 of the 77 survey farms. It is equipped with a cylinder sheller and cleaner instead of the standard husking unit. The ear is snapped off the stalk and shelled in one continuous operation. The picker-sheller may be further classified as pull-type and self-propelled. The 54 farms used a total of 58 picker-shellers (39 pull-type and 19 self-propelled). Four of the farms used two machines. The pull-type machines, which had been on the market for 15 years, were more numerous. At the time of the study, the self-propelled machine had been available for two years.

A storage tank for shelled corn was mounted on most field shellers. The corn was conveyed from the sheller into the tank by an auger. The corn in the storage tank was emptied into a wagon or truck by gravity flow or by auger. The storage tank was optional equipment on the pull-type machine.

The pull-type machine was operated by the power take-off of a tractor. The self-propelled picker-sheller was propelled and powered by a uni-tractor designed for use with five interchangeable harvesting attachments.

The picker-and-sheller unit, which consisted of either a mounted or self-propelled ear-corn picker and a high-capacity sheller, was used on 23 farms. A trailing sheller was used on 17 and a stationary sheller on 6 of these farms.

[1] See Appendix Tables 22 through 25 for detailed information by areas on total and tillable acres, classification of farms, numbers and types of livestock, and tenure.

[2] See Appendix Tables 26 and 27 for summary of acres in all crops and disposition of corn, respectively.

The shelled corn from the trailing sheller was conveyed either into a storage tank mounted on the sheller or into a wagon pulled behind the sheller. The power was furnished by a mounted 4- or 6-cylinder gasoline engine. The sheller unit was usually operated separately and without direct control by the operator.

A third type of field sheller, the corn combine, was in limited use during the 1954 season, but operators who used it were not included in the group of cooperators who kept daily records. The corn combine is a modification of the self-propelled small-grain combine. A corn-snapping unit or corn head replaces the small-grain header. Cylinder speed, concave spacing, and sieve openings are adjusted to meet the requirements for harvesting shelled corn rather than small grain.

Hauling-and-Unloading Equipment

Shelled corn was hauled to the drier by wagons or trucks, emptied into the hopper of a conveyor, and elevated into the drying structure or holding bin. Wagons were used most frequently.

Most wagons and trucks were unloaded by a hydraulic or cable wagon-jack that elevated the front of the vehicle. These devices were powered by electric motors, gasoline engines, or a tractor.

Some farmers used self-unloading trucks and farm wagons that were equipped with a hydraulic lift. In addition, a few of the wagons were equipped with a chain drag, or an auger connected to the power take-off of the tractor.

Conveying-and-Elevating Equipment

A chain-drag multipurpose elevator was most frequently used to fill the drier because of its large capacity and because it was usually available on the farms. An auger for unloading the grain was an integral part of nearly all driers. In moving the grain from the drier to storage, it was easier to match conveying capacity by using another auger. The power to operate conveying equipment was furnished by electric motor, gasoline engine, or tractor power take-off.

DRYING INSTALLATIONS

During the past eight years, heated-air drying has become increasingly popular in Illinois (Table 1). Of the 77 driers included in this study, 90 percent were installed in 1950 or later. These 77 driers represented about half of all farm driers in use in Illinois before 1955.

Most of the drying equipment — a heater, a power-driven fan, and a container for the grain — was commercially manufactured. In some

Table 1. — Type of Drying Structures Installed on 77 Illinois Farms, 1946-1954[a]

Year installed	Total	Percentage of total	Type of drying structure			
			Batch			Continuous flow
			column	bin	wagon	
1946	1	1	1	..	..	..
1947	1	1	..	..	1	..
1948	3	4	1	1	..	1
1949	3	4	2	1	..	..
1950	10	13	6	4	..	..
1951	6	8	3	2	1	..
1952	18	24	15	1	2	..
1953	21	27	15	3	1	2
1954	14[a]	18	13	..	1	..
Total	77	100	56	12	6	3

[a] Three of these farmers had dried corn previously, but they changed driers in 1954.

instances, the heating units and drying structures were made by different manufacturers. Nine drying structures and 3 heating units were farm-constructed.

Heating Units

Although 12 makes of heating units were studied, 78 percent of all units were of 5 makes. Most of these units were portable. Fuel oil was used in 59 units, liquid-petroleum gas in 16, and natural gas in 2 units. Most of the early model driers had oil burners, but many of the recent models burned liquid-petroleum gas.

Heating units were classified as direct- and indirect- (heat-exchanger) type units. Sixty-nine direct and 8 indirect heating units were used on the 77 survey farms. In the direct type, burnt gases are combined with the heated air and the mixture is blown through the grain. Although this type of heating unit uses fuel efficiently, there is some fire hazard — and if the burner is operating improperly, the corn may be discolored.

In the indirect type of heating unit, burnt gases pass through a heat exchanger and are discharged through a stack. The air, heated as it comes in contact with the heat exchanger, is blown through the grain. This type of unit is less efficient than the direct type because some of the heat is lost through the stack, but there is less danger of fire.

At least two automatic safety controls are used with either type of heating unit: (1) a device to shut off the drier if the flame fails; and (2) a device to shut off the fuel supply if the temperature goes above

the level at which the thermostat is set. If the power on the fan fails, the temperature increases immediately and the fuel supply is shut off by the temperature control.

Drying Structures

Eleven different manufactured drying structures were used; 79 percent of all drying structures were of 6 makes. Most of the drying structures were permanent installations, and were of two general types — batch and continuous-flow. Seventy-four of the drying structures were classified as batch, and 3 as continuous-flow.

Batch drying is generally characterized by drying relatively small lots of corn. The depth of the layer of corn dried may vary from a few inches in the vertical column drier to several feet in a bin drier. Of the 74 batch-drying structures, 56 were column, 12 were bin, and 6 were wagon driers (Table 1).

Column-drying structures were both portable and stationary. Capacities ranged from 100 to 450 bushels, depending on the size or model of drier to which the structure was attached. The most typical size had a 300-bushel capacity in the drying chamber.

The heating unit and column-drying structure were commonly connected by a canvas duct. Some of the new-model heating units are connected directly to one end of the drying structure; others have the heating unit mounted partially inside the drying structure.

Column-drying structures can be distinguished by the pattern of air flow through the bins during the drying process. In one type, the air is blown into the heated-air chamber between the columns of grain and forced through the grain, which is usually 14 to 24 inches thick.

The other type of column drier has alternate rows of supply and exhaust ducts (sometimes called "baffles") that are open on the bottom and surrounded by the grain. Heated air, forced into the supply ducts, moves out of the bottom of the ducts, through the grain, and is expelled through the exhaust ducts. In this type of structure, the air moves through a thickness of about 6 inches of grain.

Most of the column-drying structures were provided with storage bins above the drying chamber to hold at least one batch of wet corn. This arrangement permitted the drying chamber to be filled rapidly by gravity and reduced delay in beginning the drying of a new batch of corn.

Bin-type drying structures served as both drying structures and as grain storage after drying was completed. A false perforated floor was installed to permit air flow through the grain. Before the heating unit was started, this floor was covered with an even layer of grain from 1 to 5 feet deep. The grain was moved from the bin either

by a conveyor installed beneath the floor or by a portable auger on top of the false floor.

Wagons with tight sides were adapted for drying by placing a perforated floor 10 to 12 inches above the bottom of the bed. One or more wagons were connected to the heating unit by a canvas duct or other material.

Continuous-flow drying is not usually considered as suitable for farm use as batch drying because of the greater control and attention necessary to operate the equipment satisfactorily. In the continuous-flow method, the shelled corn is dried and cooled as it moves through the drier. Heated air is forced through a comparatively thin layer of corn to obtain uniform drying.

STORAGE STRUCTURES

Storage structures for shelled corn represented 82 percent of all corn storage on the survey farms. Wood and circular steel structures were used for approximately three-fourths of the total shelled corn stored (Table 2). Wood storage consisted of converted ear-corn cribs, small overhead bins, and some newly constructed shelled-corn structures. Most of the new storage structures were either circular steel bins or concrete silos. Storage capacity for ear corn was not large, but 41 of the 77 farms had some storage space. Only part of it was used.

Table 2. — Total Capacity of Corn-Storage Structures per Farm, by Type, on 77 Illinois Farms Field-Shelling and Drying Corn, 1954

Type of structure	Shelled corn	Ear corn
Steel		
Average capacity, bushels	5,600	300
Percentage of total	40	10
Number of farms	43	16
Concrete[a]		
Average capacity, bushels	3,300	..
Percentage of total	24	..
Number of farms	16	..
Wood		
Average capacity, bushels	5,000[b]	2,700
Percentage of total	36	90
Number of farms	41	35
All types		
Average total capacity per farm, bushels	13,900	3,000
Percentage of total	100	100
Number of farms	77	41

[a] Includes converted concrete ear-corn cribs, and concrete stave and poured concrete silos.
[b] Primarily converted ear-corn cribs and overhead bins.

WHY FARMERS CHANGED TO SHELLED-CORN HARVESTING METHODS

Storage was the most important consideration in making the change in harvesting methods. The need for additional corn storage, the necessity for replacing worn-out cribs, and the lower cost of storage for shelled corn were the reasons given by 79 percent of the farmers.

Less and easier work was listed by 35 percent of the farmers. References to lower labor requirements were usually supplemented with statements that shelled corn was easier to handle than ear corn and that field-shelling eliminated the job of shelling from the crib and disposing of the cobs.

Reasons pertaining to earlier harvest were third and fourth in importance. Reduction of field losses and avoidance of bad weather were given as reasons by more than a fourth of the farmers. Bad weather causes greater field losses and discomfort to workers.

Other reasons for changing to field-shelling and drying of corn included less rodent and insect damage, insurance for "wet corn" years, opportunity to plow in the fall or sow wheat after corn, cheaper harvesting, improved quality of corn, and more flexibility in farm operations.

In the 1953 season, 53 percent of the cooperators (35 of 66 farms) harvested some ear corn. By the following year, the percentage had dropped to 39 percent (24 of 62 farms), and the ear-corn harvest amounted to about one-sixth of the total corn harvest.

The most common reason why the change to field-shelling was only partial on these farms was the shortage of storage for shelled corn and the availability of usable storage for ear corn. The second most common reason was that many livestock farmers prefer ear corn for feed. This preference was due either to a lack of equipment for handling shelled corn for feeding or to a reluctance to change established and farm-tested feeding systems. Other reasons for not making a complete shift to field-shelling included sheller breakdowns and production of seed corn.

MANAGEMENT PROBLEMS

Many management problems confront the operator of a field sheller and heated-air drier. Most problems fall within four groups, according to the principal jobs in the harvesting process: (1) field-shelling; (2) hauling and unloading; (3) drying; and (4) storage. Some general problems affect more than one of these major jobs.

Management of Field-Shelling

Field losses. Each year important crop losses result from corn that drops on the ground before picking and corn knocked down by the harvesting machinery. A major factor in determining the magnitude of these losses is the time of harvest. When corn is harvested early with a field sheller, the stalks are not as dry and brittle as they are later, and the corn is more likely to be standing upright. Consequently, field losses are less than those that occur by using the conventional picking method.

On the average, mechanical ear-corn pickers leave 10 percent of the corn in the field. Losses are about equally divided between ear and shelled corn.[1]

The checks on machine loss of 32 field shellers during the 1954 season averaged 6 percent of gross yield; two-thirds of the checks were between 4 and 8 percent.[2] About two-thirds of the machine loss was shelled corn, and one-third was ear corn.

In most instances, a high proportion of the shelled-corn loss was caused by the snapping rollers. This same loss would occur with a picker operating under similar conditions. These loss checks compare closely with the losses estimated by 34 cooperators who kept daily records. The average of their estimates of machine losses for the complete harvest was 5.6 percent of total yield, with a range of 1.7 to 11 percent.[3]

Detailed loss checks showed that the field shellers studied will lower field losses below those obtained with a picker only if the corn is harvested earlier, thus avoiding the late-season conditions that cause ear losses to be particularly high. Detailed loss checks and farmers' estimates for the field shellers studied in 1954 indicated that type of field sheller had little effect on field losses.

In addition to machine loss, the detailed checks showed that pre-harvest ear loss amounted to 1.7 percent. The range in pre-harvest ear loss was zero to 10 percent. A high percentage of lodged corn appeared to be the most important harvesting condition influencing losses. A high percentage of lodging was associated with high preharvest ear loss and high machine loss of ear corn.

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[1] Bateman, H. P., Pickard, G. E., and Bowers, Wendell. Corn Picker Operation to Save Corn and Hands. Ill. Agr. Ext. Cir. 697, p. 3. 1958 edition.

[2] See Appendix A for method used to estimate field losses.

[3] See Appendix Table 29 for summary of farmers' estimates of field losses, by type of field sheller.

Damp weather increased harvesting losses. The difference in dampness of the corn from morning to afternoon appeared to be significant. A summary of loss checks made on 14 machines during the morning and afternoon indicates that machine losses of shelled corn were consistently higher in the morning.[1] Losses of shelled corn were 4.6 percent of gross yield in the morning as compared with 3.0 percent in the afternoon. Ear corn lost by the machine was 2.2 percent of gross yield in the morning as compared with 2.0 in the afternoon. The difference between total machine loss in the morning and afternoon was 2 percent of gross yield, or more than one bushel per acre.

The difference in losses of shelled corn by time of day is explained by the difference in moisture of the stalks and ear shanks. In the morning, the shanks are tough and ears do not snap quickly. The ears are held on the snapping rolls longer, causing more shelling off the butt end of the ear.

Average driving speed was 2½ miles an hour, somewhat slower than the speed at which most farmers operate ear-corn pickers. At less than 3 miles an hour, speed appeared to have little effect on losses. In most instances, there was no need to operate at a higher speed because harvesting capacity exceeded drying capacity.

Operating practices recommended to reduce field losses with mechanical pickers[2] are (1) slow speed and careful driving to keep on the row; (2) picking early in the season; (3) keeping picker snouts close to the ground; (4) running snapping rolls as close as possible; (5) keeping snapping rolls in good condition; (6) checking timing of gathering chains; and (7) checking operation of the husking bed. Most of these operating procedures apply equally to field shellers in use in 1954. Except for differences in speed and time of harvest, there was little basis for expecting a difference in field losses between the two harvesting methods.

Three-fourths of the cooperators used livestock or gleaned the corn by hand to salvage part of their field losses. Cattle were used on 14 farms, beef cattle and hogs on 17, and a combination of these and other livestock on 13. Livestock could not be used on all farms because of inadequate fencing. Four farmers gleaned the dropped ears by hand. Fifteen cooperators made no attempt to recover their field losses.

Farmers' estimates of the percentage of corn recovered by different classes of livestock ranged from an average of 50 percent for beef

[1] See Appendix Table 28 for a summary of machine-loss checks by time of day.

[2] See footnote 1, p. 12.

cattle to 80 percent for hogs. Earlier harvest increases the possibility of salvaging a high percentage of the corn. Fields are usually in better condition and shelled corn is not embedded in the ground.

Harvesting Dates and Moisture Content of Corn

In 1954, the first cooperators began harvesting in central Illinois on September 18, and the last cooperator finished in northern Illinois on December 20. The following year, harvest began on September 6 and ended November 26. Although more farmers began early in 1955, about half had started harvesting by October 1 in both years. The harvest season began two weeks earlier and ended four weeks earlier in 1955 because of drier fall weather.

The number of farmers who began harvesting between October 4 and October 16, 1954, decreased sharply from the number who began during the previous two-week period (Table 3). Unusual weather was the chief cause. Temperatures from October 1 to 4 were extremely warm, with 90 degrees and above recorded at most stations (see Appendix B, "Weather Conditions Before and During Harvesting Season, 1954, page 61). The temperatures from October 4 to 8 were below normal, and were followed by severe storms and rains in northern Illinois from October 9 to 11. Thus, it was the week following the rain (October 18 to 23) before another large group of farmers began harvesting. The two weeks from October 4 to 16 were unfavorable for drying, as indicated by an increase in average moisture content of corn at the beginning of harvest.

Farmers who started harvest early were located in central Illinois, the southern part of the area studied (see Fig. 1). In this region, dry or semidrouth conditions matured corn early in 1954. The weather was not nearly as dry in northern Illinois. Some of the farmers in that area began to harvest during the last of October and the first week in November at moisture contents ranging from 26 to 28 percent.

The important factors that influence moisture content are (1) geographic location within the state; (2) different weather; and (3) maturity dates of the many different hybrids planted throughout the area. Noticeable differences in the moisture content of corn were observed on the same farm where more than one variety of hybrids were harvested.

The full advantage of field-shelling and drying in reducing field losses is obtained by harvesting before a conventional picker could normally be used. Ear corn is not usually harvested and cribbed above 20-percent moisture, and this moisture content can be considered the dividing point between field-shelling and conventional picking.

Table 3. — Moisture Content of Corn on Beginning and Ending Harvest Dates, 45 Illinois Farms Field-Shelling and Drying Corn, 1954[a]

	Beginning of harvest			End of harvest		
	Number of farms	Moisture content, percent		Number of farms	Moisture content, percent	
		Average	Range		Average	Range
Sept. 18	2	33.5	32–35	..	....	.....
20–25	9	31.2	25–38	..	....	.....
27–Oct. 2	12	25.2	18–32	1[b]	21.0	.....
Oct. 4– 9	5	29.0	21–35	0	....	.....
11–16	3	28.7	28–30	6	20.5	19–23
18–23	11	25.5	22–28	6	18.3	17–21
25–30	2	22.5	18–27	9	18.3	15–22
Nov. 1– 6	1[b]	26.0	.....	6	18.7	15–22
8–13	..	....	.....	5	18.3	15–20
15–20	..	....	.....	4	19.8	17–22
22–27	..	....	.....	4	18.0	17–19
29–Dec. 4	..	....	.....	0	....	.....
Dec. 6–11	..	....	.....	2	20.5	20–21
13–20	..	....	.....	2	18.5	18–19
Total	45			45		

[a] Forty-five of the original 77 cooperators kept detailed daily harvesting records.
[b] On October 1 the first cooperator completed his corn harvest, and on November 1 the last cooperator began harvesting.

At 21-percent moisture and above, 43 of the 45 farmers who kept records had begun harvesting, and 11, or approximately a fourth, had finished harvesting (Table 4). This fact indicates the extent to which farmers were able to take full or partial advantage of the opportunity to harvest early. An even better indication is given by the percentage of the total crop harvested at various moisture contents. Approximately two-thirds of all corn was harvested at moisture contents of 21 percent and above.

Farmers with large acreages cannot normally field-shell and dry all of their corn before the moisture drops to 20 percent, the safe moisture content for storage of ear corn. On the basis of an expected 0.5 to 0.6 percent drop in moisture content each day and an average harvesting rate of 4.1 acres a day,[1] a farmer who began harvesting with 30-percent moisture could harvest 70 to 80 acres before the corn was dry enough to pick and crib. Records of 11 farmers who began harvesting at moistures of 28 to 32 percent indicated that they field-shelled and dried 4,000 to 7,000 bushels at moisture contents of 21 percent and above.

[1] The field-shelling rate of 4.1 acres a day was based on average length of harvesting season and average total acres of corn for all farms (Appendix Table 29). Length of harvest included all elapsed days.

Table 4. — Moisture Content of Corn at Beginning and End of Harvest Compared with Percent of Total Crop Harvested, 45 Illinois Farms Field-Shelling and Drying Corn, 1954

Range of moisture content (percent)	Beginning of harvest		End of harvest		Percent of total crop harvested
	Number of farms	Percent of farms	Number of farms	Percent of farms	
38–31	9	20	..	..	3
30–26	21	47	..	..	15
25–21	13	29	11	24	46
20–15	2	4	34[a]	76	36
Total	45	100	45	100	100

[a] The 34 farms that completed harvest below 21-percent moisture content included 8 farms at 20 percent, 6 farms at 19 percent, 11 farms at 18 percent, 5 farms at 17 percent, 1 farm at 16 percent, and 3 farms at 15 percent.

These averages seem small when compared with reports from farmers who harvested 1,200 to 1,400 bushels in a single 9-hour day. A few farmers harvested 17,000 to 23,000 bushels within the range of 32- to 21-percent moisture content. The primary reasons for the low average field-shelling rates were (1) weather; (2) competition with other crop work; (3) limited capacity of drier at high moisture contents; (4) machinery breakdowns; and (5) competition with livestock work.

The first three reasons were the most important. Soybeans have first priority in harvesting. Soybean losses because of adverse weather are relatively more serious than losses from late harvesting of corn. All of these factors limit the maximum output of a field-shelling and drying system. Importance of specific factors to an individual farm will depend on type of farm, available labor, and type of harvesting equipment.

Management of Hauling and Unloading

Hauling and unloading grain, when coordinated with the jobs of field-shelling and drying, was a relatively simple part of the entire process of harvesting. However, loss of time and delays were noted in some instances. These were caused by (1) too few wagons or trucks; (2) wagons or trucks improperly located in the field for convenient loading; and (3) the hauler delayed at the drier.

On a few farms, the drying capacity was reduced by slow and improperly matched loading and unloading conveyors. This problem occurred particularly in unloading the drier, since more than one auger or elevator was usually involved.

Some farmers utilized the overhead bins and permanent elevators located in their ear-corn cribs as part of their grain-handling system. High-moisture corn was elevated to an overhead bin and then fed into the drier by gravity or with an auger. Not much time was saved in conveying the corn by auger from an overhead bin as compared with filling the drier directly from wagons or trucks. But regardless of the location and method of unloading, the overhead bin was valuable in reducing the number of wagons needed and avoiding tie-up of wagons and possible delay in the field-shelling operation.

Management of Drying

Drying systems varied considerably. In most instances, farmers adapted existing equipment, power, and buildings in planning the drying system. The type of storage influenced the layout of drying equipment. If steel bins were used, drying equipment and storage structures were located so that corn could be moved to storage from a central elevator or a portable auger. With some of the converted ear-corn cribs, the central elevator was used to fill the drier and to move the corn into storage after drying.

Farmers who had equipment and buildings designed to fit and work together avoided trouble and extra expense. The most satisfactory drying systems had the following characteristics:

1. A convenient, centralized location with adequate space for moving vehicles for loading and unloading grain.
2. Light and power conveniently centralized so that augers, conveyors, hoists, fan, etc. could be controlled easily with a minimum number of steps for the operator.
3. A size and type of drier to fit the needs of the particular farm, depending on size of crop, available labor, and speed of harvesting desired.
4. Overhead storage for holding at least one batch of high-moisture corn.

On most farms, the heated-air drier was new equipment and required a certain amount of "learning by experience." The technical and engineering aspects of drying are different from and more complicated than the operation of most farm machinery. Even though each manufacturer prescribes specific operational procedures, a high level of managerial ability and supervision is required. Some driers are equipped with automatic controls, but basic drying principles must be completely understood and followed for a successful drying operation.

The objective in drying is to reduce the moisture content to the desired level (13-percent moisture content for extended safe storage and 15.5 percent for market corn) without damaging the corn. Shelled corn stored for extended periods with more than 13-percent moisture may heat and spoil. Drying corn below 15.5 percent for direct marketing results in a loss because of shrinkage in weight and the operating cost of drying.

Some of the major factors involved in drying shelled corn are (1) relative humidity; (2) drying temperature; (3) cooling the grain; and (4) moisture testing.

Lowering of relative humidity. The effectiveness of any drying system — heated air or natural air — depends on the relative humidity of the air forced through the grain. Relative humidity is the amount of moisture in the air relative to the total amount of moisture the air could hold at a specific temperature. Heated-air drying operates on the principle of lowering the relative humidity of the air in and around the shelled corn to be dried.

Air of a given relative humidity can lower the moisture content of shelled corn only to a specified level. For example, at 77° F., air at 90-percent relative humidity can lower the moisture level of shelled corn to 19 percent; air at 60-percent relative humidity can lower moisture level to 13 percent; and air at 30-percent relative humidity can lower moisture level to 8 percent.[1] During wet and cold or hot and humid weather, it is necessary to heat the air to lower its relative humidity and thus increase its ability to absorb moisture from the grain.

Drying temperatures. Maximum temperatures for drying depend on the ultimate use of the shelled corn. There is considerable disagreement concerning the effect of high temperatures on grain. Apparently, the feeding value of mature corn is not affected by drying temperatures as high as 190° F.[2] Corn to be used for wet milling, in which the yield of starch is of prime importance, is adversely affected by high drying temperatures. An upper limit of 130° F. is recommended for corn to be used for wet milling.[3]

The problem of drying temperature is complicated because the farmer has only a general idea of the temperature of the air that passes through the corn. Even the operators who had thermometers placed in

[1] Coleman, D. A., and Fellows, H. C. Hydroscopic Moisture of Cereal Grains. Cereal Chem., vol. 2, pp. 275-287. 1925.

[2] Ramser, J. H. Selection of Crop-Drying Equipment. Univ. Ill. Dept. Agr. Engin. AEng 645 (mimeo), p. 3. 1952.

[3] Shedd, C. K. Mechanical Drying of Corn on the Farm. U. S. Dept. Agr. Cir. 839, p. 17. 1950.

the corn knew the temperature of the air at one point only; they did not know the maximum temperature of the corn.

On one of the farms studied, the corn in the drier nearest the air stream was regularly scorched to such an extent that the damage was visible. The temperature was too high for the rate of air flow.

In another instance, the temperature in the air stream of the drier was found to be 25 degrees higher than the operator thought it was. Some of the driers were equipped with interchangeable fuel jets that furnished a constant flow of fuel per hour. This constant rate of fuel consumption resulted in a temperature differential of 60 to 80 degrees between the outside air and the heated air. When the outside temperature was 90 degrees, the corn was subjected to a temperature of 150 to 170 degrees. With cooler weather, the drying temperature was correspondingly lower. Even though the fuel jets could be changed to compensate for changes in weather, early morning and afternoon temperatures varied greatly on many days. On some driers drying temperatures were automatically controlled by thermostats rather than by changing fuel jets.

Cooling grain. All grain must be cooled to outside temperatures after it is dried with heated air. Corn stored at a high temperature may heat and spoil. In addition, high temperature in stored grain may cause rapid moisture migration. Continued ventilation of the grain after the heat is shut off cools the corn and tends to equalize the differential in moisture content of the various layers of grain. The lack of uniformity in moisture content is further overcome by mixing the grain as it is conveyed from the drying structure to storage. With a given temperature and air flow, an increase in depth of the corn being dried will increase the differential in moisture content.

Moisture testing. Artificial drying requires a high degree of control to obtain desired results. One of the major means of control is accurate moisture testing.

Ordinarily, moisture tests were made of all loads and batches of corn early in the season or at intervals during the season, drying time was calculated, and this standard was used as the basis for much of the operation. A few farmers kept a record of each batch, including moisture tests before and after drying, drying time, drying temperature, and weather. Nevertheless, the final moisture content of dried corn frequently varied from the desired level. When less care was taken, the lack of control often resulted in costly mistakes.

Drying difficulties were due primarily to lack of understanding of the technical relationships of drying temperatures, relative humidity,

airflow, drying time, and moisture levels of corn; sampling techniques that failed to provide representative samples for testing; and the unreliability of some moisture testers under farm conditions.

Methods of taking samples for testing were generally inadequate. Grain probes were not used and efforts were not always made to obtain a well-mixed composite sample from different points in the load or batch. Complete control is based on tests at three different stages: (1) before drying begins, to find out how much moisture is to be removed; (2) during drying, to check the amount of moisture removed and whether estimated drying time was accurately determined; and (3) final moisture content, to be sure the grain is dry enough for storage. It was not difficult to take samples for testing before drying. With most of the driers studied, however, it was not possible to get a composite sample from the corn in the drier. Samples for testing after drying were taken as the drier was unloaded, and the corn was in storage before tests were completed and mistakes discovered.

Other uses for the drier. The volume of other crops dried was not large, but on some farms the use of drying equipment with other crops reduced the overhead cost of ownership. The total quantities of crops other than corn dried by 24 farmers were as follows: soybeans, 10 farms, 6,100 bushels; oats, 11 farms, 800 bushels; wheat, 8 farms, 800 bushels; rye, 1 farm, 1,000 bushels; and hay, 4 farms, 115 tons. Some of the farmers dried three crops in addition to corn.

The indirect benefits of drying other crops are worthy of consideration. For example, the use of a heated-air drier may speed up soybean and small-grain harvesting to such an extent that unfavorable weather is avoided. Combining can be extended to more hours per day, since extra moisture is not a problem in grain harvested early in the morning. Hay drying may result in increased feeding value and quality of feed.

Two farmers air-conditioned their central hog houses by using the drier fan for cooling in summer and the heating unit for winter. On two other farms, a machine shed and a large poultry house were also heated by farm driers.

Insurance against fire. Fire is a risk in operating a heated-air drier. In most instances, the farmers insured their driers and buildings against the possibility of damage from fire. A few had difficulty in getting insurance. Since the drier is a relatively new kind of machine, some insurance companies hesitated to insure not only the drier but the entire setup, including storage structures and the grain. Replies from 45 farmers indicated that 34 had regular fire insurance policies, 4 had short-term policies with a rider, and 7 did not insure.

Management of Storage

In August, 1955, a storage-and-marketing questionnaire concerning the 1954 corn crop was mailed to 70 cooperators. Of the 57 farmers who replied, 37 reported storage difficulties as follows. (Some of the farmers listed more than one storage problem.)

	Number of farmers
Crusting and spoilage on top of bin	16
Heating	14
Insects (weevil damage)	14
Cracked and broken kernels	5
Dirty corn	4

According to their 1954 daily harvesting records, 22 of the 30 farmers who reported either heating or crusting had stored one or more batches of shelled corn at moisture contents ranging from 13 to 17 percent. Fourteen of these 30 farmers reported average final moisture contents for the season ranging from 13 to 15.6 percent.

These facts indicate that much of the trouble was caused by the excessive moisture content of stored corn. Some farmers did not realize that one batch of wet grain in a bin may heat or mold, even though the grain above and below the batch is dry.

Storage management begins in the field with the field sheller and continues until the corn is either fed or marketed. To insure extended safe storage, shelled corn should be clean, have the proper moisture content and temperature, and be stored in an adequate and sound structure.

Cleanliness of corn. Accumulations of cracked and broken kernels and dirty corn are especially susceptible to insect infestation and heating. Under normal harvesting conditions, the amount of cracked corn and the quantity of dirt, chaff, and cobs can be minimized by properly adjusting and operating the field sheller. But despite proper adjustment of the field sheller, corn shelled at moistures of 28 to 30 percent and above contains more cobs and husks and considerably more broken and chipped kernels than that shelled at lower moistures. Another source of cracked and damaged kernels is improperly operated elevators and conveyors.

Experience with the storage of shelled corn has shown the value of excluding fine material such as grain dust and chaff; nevertheless, only about a third of the farmers attempted to clean their corn as it was moved into the drier or into storage.

The farmers who cleaned their corn used several methods and types of equipment. Although much of the equipment was improvised and farm-built, with household-type fans used in most instances, considerable cleaning was accomplished.

The following cleaning methods were used:

1. Fan directed at stream of corn as it came from the drier outlet or as it emptied into the storage bin (13 farms).
2. Screen wire trough with a fan directed against the flow of grain (4 farms).
3. Drier fan operated while filling and emptying drying structure (4 farms).

Even when an attempt is made to clean the corn, a certain amount of fine material will accumulate, but it should not be allowed to concentrate in one area of the bin. Preferably, the corn should be sprayed over the entire bin — at least the spout should be moved from time to time.

Moisture content and temperature. Corn should be dry and cool to prevent spoilage during extended periods of storage. The moisture content of the shelled corn must be below 13 percent for year-round storage. This moisture content should be the upper limit of the wettest corn in the bin, not the average of the total mass of grain. Corn cooled to 40° to 50° F. will retard moisture migration and insect infestation.

Adequate structure. The main requirements of a satisfactory storage structure are (1) control over moisture content of the stored grain; (2) structural soundness; (3) protection of grain against damage by rodents and insects; and (4) a convenient arrangement for filling and emptying the building.

Control over moisture content of the stored grain involves preventing entrance of moisture from the outside and migration of moisture to the upper layers of grain in fall and winter. Spoilage from moisture migration can be prevented by installing perforated pipes or ducts in the bin with an attached small-capacity fan. During cold weather, air can be drawn through the grain to equalize temperature and prevent movement of moisture to the upper layers. Grain storage should be weathertight to protect the grain from moisture from rain or snow coming through the roof, walls, or around the foundation.

Shelled corn requires a stronger structure than ear corn because of greater pressure against walls and supports, and the weight on the floor and foundation. Failures from poor construction result in costly repairs and loss of grain. Cribs for ear corn that are converted to storage

for shelled corn by making the sides tight must be strengthened with crossties to withstand the increased outward pressure. Silos built for corn silage must be strengthened by extra banding, similar to that required for storage of grass silage.

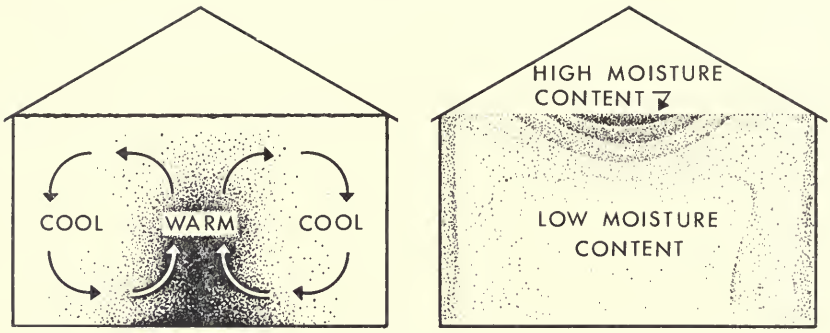
Most storage structures for shelled corn are so designed that damage from rats and mice is almost eliminated. Birds can be kept out by screening the ventilators and other openings. If the corn is stored in a clean, tight structure at the proper moisture level, insect infestation is reduced. Sufficient space should be provided for complete inspection, and for fumigation if necessary. The tightness of storage structures for shelled corn facilitates successful fumigation.

Storage structures should be built so that they can be filled and emptied with mechanical equipment or by gravity. They should also be designed to utilize portable or permanent augers or elevators to move the grain into and out of storage with a minimum of hand scooping.

Moisture migration.[1] One difficulty encountered in storing shelled corn for more than a few months is the migration of moisture to the upper levels (Fig. 2). In fall and winter, when the bin wall and the grain near the wall become colder than the grain at the center of the bin, convection currents are created. The temperature of the air that moves slowly upward in the central part of the grain rises from contact with the comparatively warm grain. At the same time, the relative humidity of the air is increased by moisture removed from the grain. When the rising air comes in contact with the cold grain near the top surface, some of the moisture from the air condenses. The moisture content of the top layer of grain is raised, but the net moisture of the entire mass of grain is not increased. In fact, a slight decrease in net moisture may occur. Serious accumulations of moisture can occur even with grain otherwise dry enough for safe storage.

Usually no serious damage takes place until midwinter, although excessive moisture may accumulate on the upper surface early in the fall. This condition occurred during the fall of 1954, when the early and rapid moisture migration was accentuated by two factors. Some farmers harvested early, while the outside temperature was around 90° F.; and even though the corn was cooled, it moved into storage at a relatively high temperature. During the latter part of September and in October of 1954, a series of abnormally high and low temperature

[1] For a more detailed discussion of moisture migration, see "Mechanical Ventilation of Stored Grain" by R. N. Robinson, W. V. Hukill, and G. H. Foster, Agricultural Engineering, vol. 32, pp. 606-608, 1951; and W. V. Hukill, "Grain Cooling by Air," Agricultural Engineering, vol. 34, pp. 456 and 458, 1953.



Moisture Migration. Convection currents moving through the grain during the fall and winter (left) cause moisture to accumulate in the upper layers of the grain (right). (Fig. 2)

periods occurred.[1] The periods of low temperatures were long enough to cause movement of moisture. The warm periods that followed caused heating in several bins. Two farmers reported that corn sprouted on the upper surface of their bins.

Conditioning corn. Five farmers who had the equipment for grain conditioning ventilated their shelled corn for an average of 40 hours each. Judging from the number of farmers who reported heating and crusting, several others needed some means of conditioning shelled corn after storage.

A study of government-stored corn in Iowa during 1952-53 shows the effectiveness of small-capacity ventilating equipment in reducing moisture migration. On February 1, 1953, the moisture tests of corn from the top foot of grain at the center of 18-foot-diameter bins averaged 19.2 percent for non-ventilated bins and 14.3 percent for ventilated bins. On March 15, moisture tests averaged 18.8 for non-ventilated bins and 15.1 percent for ventilated bins. For a bin with a diameter of 18 feet and a capacity of 3,200 bushels (a popular size for farm bins), 50 to 100 cubic feet of ventilation per minute seemed adequate. (See Hukill reference, page 23.)

Treatment for heating and crusting. Although a few farmers used ventilating equipment to prevent moisture migration and consequent heating and crusting, the usual practice was to stir the surface of the corn with a rake or fork. In extreme instances, the grain was removed

[1] See Appendix B, "Weather Conditions Before and During Harvesting Season, Illinois, 1954."

from the upper part of the bin and disposed of, fed, or even redried. These procedures required considerable supervision and labor, and often they did not correct the trouble but merely reduced temporarily the seriousness of the spoilage.

Insect infestation. Destructive insect infestation is favored by grain that is warm and has a high-moisture content, and by trashy and dirty areas in the corn. Since a number of farmers had trouble with heating and spoilage, it was not surprising that weevil damage was reported by 14 of the 57 farmers who replied to the storage questionnaire.

Inspection of grain. It is important to leave the upper surface of the grain level enough for inspection. An additional reason for leveling the grain is to prevent accumulation of moisture in the high area. Although most farmers inspected their corn at least once a month, the frequency of inspection of stored corn ranged from no inspection to once a week.

CUSTOM WORK

Custom work or cooperative ownership may be necessary to justify an investment in field-shelling and drying equipment. Economic justification of this equipment depends, in most instances, on a relatively large acreage of corn. Some farmers recognized this fact by contracting for custom field-shelling and drying to reduce annual overhead costs.

Field-Shelling

During the 1954 harvesting season, approximately a third of the cooperators did some custom field-shelling. The amount of custom work ranged from 20 to 167 acres, averaging 75 acres for each custom operator.

Three different methods of charging for field-shelling were used with about the same frequency. The range of rates varied widely, but within each method one rate was most commonly used: (1) $4.00 an acre plus 2 cents a bushel; (2) $6.00 an acre; and (3) 10 cents a bushel. The reports of custom rates for 1955 indicated that these three rates were still most commonly used, with $6.00 per acre most frequently charged. Field-shelling custom rates were lower than the combined custom-picking and custom-shelling rates.

In 1954 and 1955, no custom work was reported by operators who used pickers and trailing shellers. These field-sheller combinations were found on unusually large farms whose operators apparently had no time for additional harvesting.

Drying

Although custom drying was relatively unimportant for most farmers, it was an important factor on some farms. Ten of the 77 cooperators custom-dried an average of 3,900 bushels per farm in 1954. Rates for custom drying ranged from 5 to 16 cents a bushel and from ½ to 1 cent for each percentage point of moisture removed. The most common rate was 10 cents a bushel.

MAN-AND-MACHINE TIME FOR THE HARVESTING PROCESS

Using the work-simplification technique, a detailed man-and-machine study was made of the complete process of field-shelling, drying, and storing shelled corn on 23 farms. The harvesting process was broken down into three jobs: (1) field-shelling; (2) hauling and unloading; and (3) drying, which included movement of corn to storage. Each job was further divided into operations.[1]

The objective of this study was to obtain time standards as a basis for recommending more effective use of labor and equipment in the complete harvesting process, from field-shelling to storing the grain.[2] The work involving men and machines in the process of corn harvesting was of a multiple nature — one man with more than one machine or several men with several machines. In addition to the objective of developing better time standards for man-labor and machine work, the work-simplification study provided a means of learning first-hand some of the practical techniques of adapting the harvesting process to farm conditions. It provided experience that was utilized in interpreting and analyzing the detailed farm records.

A stop watch was used to time the various operations in the man-and-machine studies. Sketches were made of buildings and machine arrangements with notations as to the type and characteristics of this equipment. Notes were made of any observations that seemed pertinent to the study.

Man-Hours Used

In the summary of labor use by harvesting jobs and different sizes of crews (Table 5), all jobs were divided into specific operations to isolate factors that contributed to differences in total time. The recording of time by size of crew was complicated by occasional part-time

[1] See Appendix C for definitions of operations of each job.

[2] Vaughan, L. M., and Hardin, L. S. Farm Work Simplification, p. 108. John Wiley and Sons, Inc., New York. 1949.

family labor — wife, grandfather, and children after school. The one-man crew performed all operations. The work of the two-man crew was divided, with one man performing the field-shelling and the other hauling and unloading the corn and operating the drier. The three-man crew normally used one man for each of the jobs of field-shelling, hauling and unloading, and drying. In the three-man crew, the man who operated the drier was often occupied part-time with livestock chores or even other crop work.

Field-shelling. Field-shelling was divided into five operations (Table 5). The differences in operating time of field-shellers for 100 bushels of corn were influenced by the speed of the machine and the yield per acre. The median time required — 38 minutes per 100 bushels — represents an average speed of 2.7 miles an hour and a yield of 70 bushels an acre. The average speed of field-shelling ranged from 1.8 to 4.6 miles an hour.

The speed of the machine in operation was influenced by the size of the crew and the number and duration of trouble stops. To avoid

Table 5. — Man-Labor per 100 Bushels Used in Field-Shelling, Hauling and Unloading, and Drying Corn, for Different Sizes of Crews, 23 Illinois Farms, 1954

Jobs and operations[a]	1-man crews (5 farms)	2-man crews (15 farms)	3-man crews (3 farms)	All crews (23 farms)			
				Average		Median	Range
Field shelling	*min.*	*min.*	*min.*	*min.*	*perct.*[b]	*min.*	*min.*
To rows	2.7	2.7	2.2	2.6	4	2	1–8
Field-shell[c]	31.5	43.4	37.8	40.1	67	38	23–59
Trouble stops	2.7	8.7	2.2	6.4	11	4	0–43
Unload or change wagons	3.5	5.2	5.2	4.8	8	5	1–10
Maintenance[d]	5.6	5.6	5.6	5.6	10	6	....
Delay[e]	(0)	(1.7)	(8.7)	(2.3)		(0)[e]	0–23
Total	46.0	65.6	53.0	59.5	100	55	
Hauling and unloading							
Drive	8.8	10.2	7.6	9.6	35	10	3–20
Prepare to unload	3.2	4.0	3.3	3.7	13	3	1–8
Unload	9.3	10.6	8.7	10.1	37	10	5–21
Trouble	.1	.1	.3	.1	0	0	0–1
Load or change wagons	2.0	4.8	5.0	4.2	15	4	1–11
Delay[e]	(0)	(19.9)	(26.9)	(16.5)		(16)	0–40
Total	23.4	29.7	24.9	27.7	100	27	
Drying							
Fill drying chamber	1.1	1.4	1.7	1.3	7	1	1–9
Check and supervise	1.4	5.5	26.3	7.4	43	3	1–27
Store dry corn	6.8	9.6	7.9	8.7	50	8	5–16
Total	9.3	16.5	35.9	17.4	100	12	
Total minutes	78.7	111.8	113.8	104.6		94	

[a] See Appendix C for definitions of operations by specific jobs.

[b] Represents operation time as a percentage of job time. Exclusive of delay time, field-shelling represents 59 percent, hauling and unloading 25 percent, and drying 16 percent of total time.

[c] Includes 14 pull-type and 5 self-propelled picker-shellers, and 4 picker-and-sheller machines.

[d] Estimated on basis of 30 minutes for each 5 hours of machine operations. Only 9 of 23 time studies included a maintenance period.

[e] Delay time is not included in totals.

delay in drying, the one-man crew tended to increase the speed of field-shelling as the season progressed. Although trouble stops included adjusting snapping rolls and repairing and replacing chains and belts, most of the time was used in clearing stalks caught on the snouts and clogged between snapping rolls. A high percentage of leaning and lodged corn increased this type of trouble. Difficulties with clogging in the sheller were particularly noticeable with varieties of corn that had heavy foliage and thick husks.

Delays in field-shelling were caused by the hauler's failure to return with empty wagons, an insufficient number of wagons, and a slow drying rate. The median delay time was zero, with average delay per 100 bushels increasing with the size of crew.

Total time required for field-shelling was not critical compared with other jobs. Except for major repairs, field-shelling was seldom the limiting factor in determining the total time required for the complete harvesting cycle. Therefore, attention should be given to reducing field losses through slow and careful driving, reducing breakdowns by more careful and timely preventive maintenance, and safety.

Hauling and unloading. Hauling and unloading included five operations (Table 5). The operations of preparing to unload and unloading the grain were more important with driers that were not equipped with overhead storage for the high-moisture corn. Without overhead storage, filling the drying bin required an additional 13 minutes per 100 bushels in total machine-drier time.

Some delay normally occurred whenever more than one man was involved in the harvesting process. Unless the hauling distance was very long, the man in the two- and three-man crews who hauled and unloaded had some free or delay time. In the two-man operation, free time was usually utilized profitably in supervising, checking, and recording data on the drying operation.

Drying. Labor required to operate the drier represented a relatively small part of total harvesting time. A fixed amount of labor was required to start and turn off the heat, and to move the corn into and out of the drying chamber. Variations in the time required for filling the drying bin and storing dry corn were caused by differences in capacity and arrangement of conveying equipment.

Time used in checking and supervision increased with size of crew. This operation was the most variable as well as the most critical in the control and success of the complete harvesting process. In recording the time for checking and supervision, only that time used in actually performing some work element of the operation was included.

The one-man crew took a minimum of time for checking and supervision. In some instances, operators checked only to assure that the heating unit was functioning properly. The time used for checking and supervision varied from practically zero for the one-man crew to the full time of one man in some of the three-man crews. Time per 100 bushels for checking and supervision of the drying operation by size of crew averaged 1.4 minutes in the one-man operation, 5.5 minutes in two-man crews, and 26.3 minutes for three-man crews (Table 5).

There was a positive correlation between number of man-hours needed in the drying operation and both number of bushels per batch dried and number of pounds of water removed per batch.[1] However, the relation between man-hours and pounds of water removed per batch was very low, indicating that labor requirements for drying were not greatly affected by differences in moisture content of corn.

Machine-Drying Time

Total machine-drying time per 100 bushels decreased as the moisture content of corn fell during the harvesting season. The quantity of water removed became less and resulted in reduced heating time required per bushel. As the corn lost moisture, the total machine-drying time per 1,000 pounds of water removed increased. About the same amount of cooling time per batch was required, regardless of the amount of moisture removed.

For example, the fuel oil column-type drier (Table 6) required 2.32 hours to dry 100 bushels at 8 pounds of water removed per bushel, as compared with 1.37 hours required to dry 100 bushels at 4 pounds of water removed per bushel. Using the same situations, 2.80 and 3.43 hours respectively, were required to remove 1,000 pounds of water.

Coordination of man-and-machine time. In the process of field-shelling and drying corn, the requirements of man-and-machine time change from the beginning to the end of the season with any system and type of equipment. Complete utilization of man-and-machine time occurs for only a short period during the harvesting season. Under assumed conditions, the efficient use of man-and-machine time is a function of the number of men in the crew, type of field-shelling and drying equipment, and the moisture content of the corn.

The problem of organization was illustrated by computing man-and-machine hours for two situations representing different times in the harvesting season. Man-and-machine times per 100 bushels (Tables 5

[1] The coefficient of correlation (r) for man-hours and bushels per batch was +.407 and was significant at the 5-percent level. The coefficient of correlation (r) for man-hours and pounds of water removed per batch was +.109.

Table 6. — Average Hours of Machine-Drying Time for 23 Heated-Air Driers, by Type of Fuel and Drying Structure, Illinois, 1954[a]

	LP, column	Oil, column	Oil, bin	Oil, wagon
Number of driers	6	13	3	1
Moisture content				
Beginning	21.9	21.5	19.3	22.4
Final	13.0	12.7	12.3	14.0
Temperature, degrees F.				
Average	162	150	138	180
Median	170	150	140	....
Range	140–180	135–180	123–150	....
Machine-hours to remove 1,000 pounds of water				
8 pounds of water removed per bushel				
Heating[b]	1.39	2.38	3.98	4.21
Cooling[c]	.34	.42	.27	1.19
Total	1.73	2.80	4.25	5.40
4 pounds of water removed per bushel				
Heating[b]	1.39	2.38	3.98	4.21
Cooling[c]	.70	1.05	.52	2.38
Total	2.09	3.43	4.50	6.59
Machine-hours per 100 bushels				
8 pounds of water removed per bushel				
Heating[b]	1.11	1.90	3.18	3.37
Cooling[c]	.28	.42	.21	.95
Total	1.39	2.32	3.39	4.32
4 pounds of water removed per bushel				
Heating[b]	.56	.95	1.59	1.68
Cooling[c]	.28	.42	.21	.95
Total	.84	1.37	1.80	2.63

[a] A complete batch of corn was timed for machine-heating-and-cooling time for 23 driers. All data were adjusted to comparable heating time on the basis of pounds of water removed and to cooling time on the basis of bushels dried.

[b] Heating time was assumed to be a function of water removed, with drying temperature and humidity remaining constant.

[c] Cooling time was assumed to be a function of bushels, with drying temperature and humidity remaining constant.

and 6) were used to build up total hours required for field-shelling, hauling and unloading, and drying for different volumes in bushels, pounds of water removed per bushel, and sizes of crew (Table 7).

All man-hours, except those involved in delay and supervision, were standardized on the basis of median time from Table 5. Delay and checking and supervising were based on averages determined by size of crew. Total drying time was computed from the standardized heating and cooling times of the fuel oil column-type drier (Table 6).

A 10-hour day for each man was used to construct man-hour use. The category of free time included time that might be used for work other than that connected directly with the harvesting process. Free time may all be delay time, or it may be time used in performing live-

stock or other crop work. The complete utilization of 10-hour days for the two- and three-man crews depends on the labor requirements of the individual farm.

The first situation, using 600 bushels with 8 pounds of water removed (Table 7), is typical of a midseason harvesting situation. For purposes of comparison, the same volume of corn field-shelled and dried is used for all crews. Under these conditions, the drying operation is the limiting factor with all crews.

During a 10-hour day, the one-man crew is almost completely occupied. A major repair stop or trouble in field-shelling could easily result in a delay of the drier. The two-man crew has considerable free time (8.3 hours) that could be used to increase the total number of bushels field-shelled if the operation were not limited by the drier.

Table 7. — Machine-and-Man-Hours Required to Field-Shell, Haul and Unload, and Dry Different Volumes of Corn as Related to Amount of Moisture Removed per Bushel and Size of Crew

Jobs and operations	Removal of 8 pounds of water per bushel, 600 bushels per day			Removal of 4 pounds of water per bushel, 900 bushels per day		
	1-man crews	2-man crews	3-man crews	1-man crews	2-man crews	3-man crews
	Man-hours[a]					
Field-shell	5.5	5.5	5.5	8.3	8.3	8.3
Haul and unload	2.7	2.7	2.7	4.0	4.0	4.0
Fill drier	.1	.1	.1	.2	.2	.2
Check and supervise	.3	.6	2.7	.4	.9	4.0
Delay	0	2.0	2.7	0	3.0	4.0
Store dry corn	.8	.8	.8	1.2	1.2	1.2
Total	9.4	11.7	14.5	14.1	17.6	21.7
Free time[b]	.6	8.3	15.5	0	2.4	8.3
Total man-hours	10.0	20.0	30.0	14.1	20.0	30.0
	Machine-hours, drier[c]					
Fill drier	.1	.1	.1	.2	.2	.2
Heating	11.4	11.4	11.4	8.6	8.6	8.6
Cooling	2.5	2.5	2.5	3.8	3.8	3.8
Store dry corn	.8	.8	.8	1.2	1.2	1.2
Delay	0	0	0	.3	0	0
Total machine-hours	14.8	14.8	14.8	14.1	13.8	13.8

[a] Times for delay and checking and supervising of drying were based on averages for different crews (Table 5). Delay represents an average expected man-hour delay caused by waiting on some job. Both delay and time for checking and supervising were based on averages determined for each size of crew. All other times were standardized at median value recorded for each operation (Table 5).

[b] Free time equals total available man-hours — assumed 10-hour day for each man — less the total man-hours required for entire process of field-shelling, hauling and unloading, and drying, including average delay time.

[c] Machine-drying-and-cooling time is based on machine-hours per 100 bushels of the fuel oil column drier (Table 6).

Over half of the total available time of the three-man crew is free time.

A practical means of utilizing the free time of both two- and three-man crews is to increase the number of batches. By coordinating and spreading man-hours over a longer period, both the two- and three-man crews can increase harvesting and drying by another batch (300 bushels). Four batches would be impossible with a three-man crew because drier time would be in excess of 24 hours.

The second situation, with 4 pounds of water removed per bushel from three batches, or 900 bushels, is representative of the latter part of the harvesting season (Table 7). As the moisture content drops during the season, with an increase of 300 bushels per day, free time for the one-man crew is eliminated, and delay in machine-time for the drier is caused by a shortage of man-hours. A total of 14.1 man-hours is necessary for the one-man crew to perform all operations.

With the reduction in pounds of water removed per bushel, the drier still limits the two- and three-man crews to 900 bushels unless man-hours are spread over a period longer than 10 hours. An increase to 1,200 bushels required 11 hours for field-shelling. Thus, the two- and three-man crews are limited to about 900 bushels by both the field sheller and the drier.

CHANGES IN EQUIPMENT AND STORAGE STRUCTURES, 1954 TO 1955

A group of the 1954 field-shelling and drying cooperators was selected for restudy after the 1955 harvest season. A survey questionnaire was completed on 19 farms to determine changes made in equipment since 1954 and the reasons for these changes.

Field-Shelling

The changes in field-shelling machinery were the most significant. Four of the 19 farmers had changed from pull-type field shellers to self-propelled machines, and the three makes of self-propelled field shellers then available on the market were represented. This change was not surprising for two reasons. First, during the last few years, there has been a trend from pull-type to mounted or self-propelled pickers. Second, two of the three makes of self-propelled field shellers were first introduced during 1955.

Farmers gave these reasons for making the change in field-shelling machines: (1) self-propelled machines were better adapted to custom work; (2) fields could be opened without using a picker and then hav-

ing to dispose of ear corn; and (3) self-propelled machines were easier to drive and handle, especially in lodged or down corn.

Hauling

One farmer added another wagon to lend more flexibility to the hauling and accumulation of corn. The additional wagon was especially useful in fields with long rows. When the storage tank on the field sheller does not have sufficient capacity for a complete round, wagons spotted at each end of the field reduce the amount of driving to load wagons.

Drying

Two farmers converted their heating units from fuel oil to LP gas. The reduction in drying time was given as the main reason for this change. One farmer indicated that the conversion had shortened his drying time by at least a third.

The 1954 drying records revealed that heating units using LP gas required substantially less time to remove 100 pounds of water than those using fuel oil. The LP gas units were generally equipped with larger electric motors or adapted for tractor power take-off, thus permitting a higher rate of air movement and fuel consumption. These units were used also with larger capacity drying structures.

One farmer changed from bin drying to a column-drying structure. Bin drying was one of the first phases in the evolution of the farm-drying system for shelled corn. Bin drying is gradually being replaced by column drying, and most new installations are column-drying structures.

Storage

Changes in storage included the addition of new circular metal bins and the installation of a grain-conditioning system. The 1954 study showed that galvanized-steel storage exceeded all other types of new storage structures. The economy of construction and the opportunity to add bins in several sizes have made galvanized-steel structures quite popular.

Although grain-conditioning equipment is necessary for the safe storage of shelled corn, only one farmer added this equipment to his storage facilities. The storage experience of farmers with their 1954 corn crop indicates the need for greater attention to the problem of grain conditioning.

COSTS OF FIELD-SHELLING, DRYING, AND STORING SHELLED CORN

Field-Shelling Costs

Some of the chief advantages of field-shelling that affect total harvesting costs are (1) field losses are smaller and working conditions are better because of earlier harvest; (2) picking and shelling are performed in one operation; (3) shelled corn is easier to handle mechanically; and (4) the cobs remain in the field.

Annual field-shelling costs are directly related to the original cost of machinery and annual use in acres or bushels harvested. These two factors provide a basis for computing annual fixed and operating costs. Total field-shelling costs are comprised of machinery, power, and labor costs. Farmers' 1954 operation records on 45 field-shellers were used in determining cost estimates (Tables 8, 9, and 10).

Annual fixed costs of field-shelling included depreciation, interest on investment, taxes, and insurance on machinery and power units.[1] Fixed costs represented about two-thirds of the total annual costs of field-shelling for a volume of 10,000 bushels. As the volume of field-shelling increased, the annual fixed costs became a relatively less important part of total annual costs.

Operating costs of field-shelling included labor, fuel, oil, and maintenance and repairs. Total operating costs varied directly with the amount of use and represented about a third of the total annual costs of field-shelling for a volume of 10,000 bushels. Economies in operating costs came from organizing harvesting crews to avoid delays, timely maintenance and repairs, and fitting the power source to the required work load.

Labor was the largest item in the operating costs of field-shelling. Repairs were second in importance. The total labor and repair costs represented three-fourths of the total operating costs, as shown by the following percentage relationships of all operating costs:

	Machine	*Power*	*Labor*	*Total Operating Costs*
Labor	36	3	100	45
Repairs	58	29	...	30
Fuel	...	60	...	20
Oil and grease	6	8	...	5
Total	100	100	100	100

Average total costs of field-shelling per 100 bushels were $6.91 for

[1] See Appendix D, "Method of Computing Fixed Costs of Field-Shelling."

Table 8. — Total and Average Machine Costs of 45 Field Shellers by Type of Machine, Illinois, 1954[a]

	Pull-type picker-sheller	Self-propelled picker-sheller	Picker-and-sheller	
Number of machines	25	13	7	7
Original cost[b]	$1,920	$1,440	$1,520	$1,350
Bushels of corn field-shelled				
Home farm	7,380	8,140	14,470	14,470
Custom	1,170	3,370	.....	.....
Total	8,550	11,510	14,470	14,470
Fixed costs[c]				
Depreciation	$192.00	$144.00	$190.00	$168.75
Interest	48.00	36.00	38.00	33.75
Taxes	7.20	5.40	5.70	5.06
Insurance	4.80	3.60	3.80	3.38
Shelter	9.69	7.20	7.60	6.75
Total	$261.60	$196.20	$245.10	$217.69
Operating costs[d]				
Repairs	$53.73	$31.77	$24.33	$24.33
Labor (maintenance and repairs)	15.48	19.98	13.28	13.28
Oil and grease	2.95	3.26	5.79	5.79
Total	$72.16	$55.01	$43.40[e]	$43.40[e]
Average costs per 100 bushels[f]				
Fixed costs	$3.06	$1.70	$1.69	$1.50
Operating costs	.98	.68	.30	.30
Total	$4.04	$2.38	$1.99	$1.80

[a] Costs were computed from farmers' 1954 records.

[b] Original costs were calculated from average purchase prices reported by farmers.

[c] Pull-type and self-propelled machines were depreciated over 10 years, and the picker-and-sheller over 8 years. Other fixed costs totaled 3.625 percent of original cost.

[d] See Appendix Table 29 for average repair costs and labor for maintenance and repairs by type of field sheller. Labor was charged at 90 cents an hour.

[e] Operating costs for picker-and-sheller were recorded by farmers in a single account, and in this analysis were charged equally to the picker and to the sheller.

[f] Fixed costs were based on total corn field-shelled, including custom work. Operating costs were based on corn field-shelled on the home farm.

the pull-type machine, $6.92 for the picker-and-sheller, and $6.50 for the self-propelled machine (Table 10). These average costs do not indicate comparative costs of the different machines because of different volumes of field-shelled corn. They do show that on the average a sufficient volume of corn was field-shelled to cause average total costs of all machines to be similar.

To compare different types of harvesting machinery, and to show the effect of changes in volume, the costs of field-shelling were estimated for similar volumes of 2,000 to 28,000 bushels annual production (Tables 11 and 12).

Costs were distributed differently between the power unit and harvesting unit among the three types of field-shellers (Table 11). For example, the initial investment, and consequently the fixed costs per

Table 9. — Power Costs of 45 Field Shellers per 100 Bushels, by Type of Machine, Illinois, 1954

	Pull-type picker-sheller	Self-propelled picker-sheller	Picker-and-sheller	
Type of power	Tractor	Uni-tractor	Tractor	Mounted engine
Number of machines	25	13	7	7
Bushels field-shelled				
Home farm	7,380	8,140	14,470	14,470
Custom	1,170	3,370	....	....
Total	8,550	11,510	14,470	14,470
Hours and fuel use per 100 bushels (machine)[a]				
Hours	1.3	1.2	1.1	1.1
Gasoline (gallons)	2.9	2.6	2.3	1.4
Average costs per 100 bushels				
Fixed	$ .68[b]	$2.13[c]	$ .57[b]	$ .28[c]
Operating[d]	1.02	.91	.81	.48
Total	$1.70	$3.04	$1.38	.76

[a] See Appendix Table 29 for total hours of field-shelling and fuel consumption by type of machine.

[b] Fixed costs for tractors were charged 52 cents per hour of use — based on Illinois detailed farm account data, Appendix Table 30.

[c] Uni-tractor and mounted engine were depreciated over 10 years; other fixed costs amounted to 3.625 percent of the original investment of $2,700 for the uni-tractor and $450 for the mounted engine. Two-thirds of total costs were allocated to corn harvesting.

[d] Operating costs were computed on the basis of fuel costs, which represented 60 percent of total operating costs (Appendix Table 30). Gasoline was charged at 21 cents a gallon for median fuel consumption for each type of field sheller.

Table 10. — Summary of Average Machine, Power, and Labor Costs of 45 Field Shellers per 100 Bushels, by Type of Machine, Illinois, 1954

	Picker-sheller		Picker-and-sheller		
	Pull-type	Self-propelled	Picker	Sheller	Total
Number of machines	25	13	7	7	7
Machine costs[a]					
Fixed	$3.06	$1.70	$1.69	$1.50	$3.19
Operating	.98	.68	.30	.30	.60
Total	$4.04	$2.38	$1.99	$1.80	$3.79
Power costs[b]					
Fixed	$ .68	$2.13	$ .57	$ .28	$ .85
Operating	1.02	.91	.81	.48	1.29
Total	$1.70	$3.04	$1.38	$ .76	$2.14
Labor costs[c]	$1.17	$1.08	....	....	$ .99
Total costs per 100 bushels					
Fixed	$3.74	$3.83	....	....	$4.04
Operating	3.17	2.67	....	....	2.88
Total	$6.91	$6.50			$6.92

[a] See Table 8 for machine costs.

[b] See Table 9 for power costs.

[c] Labor was charged at 90 cents per hour for median labor use per 100 bushels. (See Appendix Table 29.)

Table 11. — Average Fixed and Operating Costs per 100 Bushels for the Machinery, Power, and Labor to Field-Shell Corn at Various Volumes, by Type of Field Sheller, Illinois, 1954

Annual volume (bushels)	Type of machine									
	Pull-type		Self-propelled		Picker		Sheller		Picker-and-sheller	
	Machine	Power	Machine	Power	Machine	Power	Machine	Power	Machine	Power
	Average fixed costs[a]									
2,000	$13.08	$.82	$9.81	$12.26	$10.36	$.82	$9.20	$2.04	$19.56	$2.86
4,000	6.54	.78	4.90	6.13	5.18	.78	4.60	1.02	9.78	1.80
6,000	4.36	.74	3.27	4.08	3.45	.74	3.07	.68	6.52	1.42
8,000	3.27	.70	2.45	3.07	2.59	.70	2.30	.51	4.89	1.21
10,000	2.62	.68	1.96	2.45	2.07	.68	1.84	.41	3.91	1.09
12,000	2.18	.65	1.63	2.04	1.73	.65	1.53	.34	3.26	.99
16,000	2.04	.60	1.53	1.53	1.61	.60	1.43	.26	3.04	.86
20,000	1.96	.56	1.46	1.23	1.54	.56	1.37	.20	2.91	.76
24,000	1.89	.55	1.42	1.02	1.50	.55	1.32	.17	2.82	.72
28,000	1.85	.54	1.38	.98	1.46	.54	1.29	.16	2.75	.70
	Average operating costs—labor not included[b]									
	$ .71	$1.02	$ .59	$ .91	$ .61	$ .81	$ .57	$ .48	$1.18	$1.29
	Labor costs[c]									
	$1.17		$1.08		.....		.....		$ .99	

[a] Depreciation costs were based on a 10-year obsolescence period or 120,000 bushels' expected life for the field shellers, 240,000 bushels' life for the uni-tractor and sheller engine, and 7,000 hours' life for the conventional tractors, whichever was the limiting factor. Other fixed costs included interest, insurance, taxes, and shelter at 3.625 percent of original cost. Two-thirds of the cost of the uni-tractor and sheller engine were allocated to corn harvest.

[b] Average operating costs of machines were based on oil and grease at 4 cents and maintenance and repair labor at 19 cents (.21 hour at 90 cents per hour) per 100 bushels; repairs were computed as 30 percent of original costs for 120,000 bushels' expected life of all machines. Power costs were computed from fuel costs representing 60 percent of total operating costs. Fuel costs were computed from median fuel consumption per 100 bushels by type of field sheller at 21 cents per gallon. (See Appendix Tables 29 and 30.)

[c] Labor was charged at 90 cents per hour based on median labor use per 100 bushels (Appendix Table 29).

100 bushels, were lower for the attachment for the self-propelled picker-sheller than for the complete pull-type harvesting machine. However, it was necessary to buy a special-purpose power unit to complete the self-propelled picker-sheller; and because of limited annual use of the special-purpose power unit, costs were very high at low volumes of harvesting.

Average operating costs of the principal power units were not greatly different (Tables 10 and 11). The tractor for the pull-type machine required more fuel because it pulled the field sheller and furnished power through the power take-off to operate the picker-and-shelling units. For the picker-and-sheller, the tractor carried the mounted picker, operated the picker, and pulled the trailing sheller. It required somewhat less power than was necessary for the pull-type machine. The average operating costs for picker-and-sheller were the highest of any of the field-shellers because two separate power units were used.

Total field-shelling costs per 100 bushels were highest for the picker-and-sheller at all volumes and least for the pull-type machine up to 18,000 bushels (Table 12). Above 18,000 bushels, the self-propelled machine was the most economical. Because of lower operating costs, the self-propelled machine was the least costly at large volumes of operation. Although few farmers harvest as much as 18,000 bushels annually, the self-propelled machine is increasing in popularity

Table 12. — Average Fixed and Total Costs per 100 Bushels for Field-Shelling at Various Annual Volumes, by Type of Field Sheller, Illinois, 1954[a]

Annual volume (bushels)	Type of machine					
	Pull-type		Self-propelled		Picker-and-sheller	
	Fixed	Total	Fixed	Total	Fixed	Total
2,000	$13.90	$16.80	$22.07	$24.65	$22.42	$25.88
4,000	7.32	10.22	11.03	13.61	11.58	15.04
6,000	5.10	8.00	7.35	9.93	7.94	11.40
8,000	3.97	6.87	5.52	8.10	6.10	9.56
10,000	3.30	6.20	4.41	6.99	5.00	8.46
12,000	2.83	5.73	3.67	6.25	4.25	7.71
16,000	2.64	5.54	3.06	5.64	3.90	7.36
20,000	2.52	5.42	2.69	5.19	3.67	7.13
24,000	2.44	5.34	2.44	5.02	3.54	7.00
28,000	2.39	5.29	2.36	4.94	3.45	6.91

[a] Fixed costs are the sum of machine and power costs (see Table 11). Total costs include operating costs of $2.90 for the pull-type picker-sheller, $2.58 for the self-propelled picker-sheller, and $3.46 for the picker-and-sheller.

over the pull-type machine because it is easier to operate, more convenient in opening fields, and better adapted to custom work.

Average costs were high at all volumes for the picker-and-trailing-sheller because of the investment and operation of separate machines and power units. However, the higher costs for this type of field-sheller do not indicate that it was uneconomical for some farmers. Its ability to harvest both shelled and ear corn, which was necessary on some farms, partly offsets the higher costs. This situation was found on large farms where seed corn was produced, and on farms where the farmers had storage for ear corn and wanted to feed ear corn to cattle and hogs. The total costs of a picker-and-sheller were less than the costs of owning and operating an ear-corn-picker and a picker-sheller.

Hauling and Unloading Costs

The 45 survey farms used an average of 78 hours to haul and unload 8,700 bushels of corn. Total labor and equipment costs amounted to $2.55 per 100 bushels of corn hauled and unloaded (Table 13).

Tractor costs, which averaged $1.00 per 100 bushels, were the most important. Labor was second in importance, requiring .9 hour at a cost of 81 cents per 100 bushels.

The usual unloading setup consisted of a wagon jack and elevator operated by an electric motor. This equipment added 49 cents to the

Table 13. — Total and Average Costs of Hauling and Unloading Corn, Illinois, 1954

	Costs	
	Total	Per 100 bushels[a]
Hauling costs		
Tractor[b]	$ 86.58	$1.00
Wagon[c]	21.00	.24
Unloading costs		
Wagon jack, elevator, electric motor[d]	43.22	.49
Electricity[e]	.87	.01
Labor[f]	70.20	.81
Total	$221.87	$2.55

[a] Based on an average of 8,700 bushels of corn per farm for the 45 farms. (See Appendix Table 29.)

[b] Tractor use was charged at $1.11 an hour (see Appendix Table 30) for an average of 78 hours' use per farm.

[c] Wagon costs were based on an investment of $375 for each of two wagons and depreciated over 15 years. One-third of the cost was allocated to the corn harvesting.

[d] Costs of wagon jack, elevator, and electric motor were based on average investments of $110, $440, and $170, respectively. This equipment was depreciated over 15 years and allocated two-thirds to corn harvesting.

[e] Electricity was computed on the basis of 600 bushels per hour for a 3-horsepower motor, amounting to approximately 1 cent per 100 bushels.

[f] Labor was charged at 90 cents an hour for an average of 78 hours per farm.

total hauling and unloading costs, with an additional 1 cent per 100 bushels for electric power (Table 13).

The number and types of wagons and trucks used varied considerably. Usually two wagons were used to haul the corn from the field to the drier. Wagon costs amounted to 24 cents per 100 bushels.

Drying Costs

Heated-air drying of shelled corn is a substitute for drying by natural means. Heated air is forced mechanically through the corn to reduce the moisture content to the desired level for storage or market.

Drying costs were influenced primarily by the original investment in equipment, annual volume of drying, and quantity of water removed per bushel. Annual drying costs, on the average, were about equal to total field-shelling costs. Drying costs included machinery, power, and labor costs. Farmers' 1954 daily performance records on 43 heated-air driers were used in computing total and average costs (Table 14). Average total drying costs per 100 bushels ranged from $6.92 for the LP gas column drier to $8.04 for the fuel oil bin drier. The difference between these two types in annual volume dried was more than 3,000 bushels. Thus, a valid comparison of the different groups of driers requires that the numbers of bushels dried and the amount of water removed be placed on a comparable basis.

The effect on operating costs of differences in quantity of water removed was eliminated by using a standard of 7 pounds of water per bushel — the average amount of water removed by all driers. (See Table 15.) Some differences in fuel requirements for the removal of a given quantity of water occur with differences in the temperature of the outside air, moisture level of the corn, and other physical factors; but the effect of these factors was assumed to be constant for all groups of driers.

Operating costs of drying included fuel, labor, electricity, and maintenance and repairs. *Fuel* was the most important. It accounted for approximately three-fourths of the total operating costs (Tables 14 and 15). Fuel oil was most commonly used — 35 cooperators used oil as compared with 8 who used LP gas. The average cost of fuel for removing 7 pounds of water per bushel ranged from $2.08 to $2.77 per 100 bushels for the three groups of driers that used oil. Fuel costs of the driers that used LP gas averaged $1.67 per 100 bushels (Table 15).

Labor was the second largest item of operating costs. It averaged 14 percent of the total (Table 15). Based on a charge of 90 cents per hour, the labor costs per 100 bushels ranged from 31 to 47 cents for the four groups of driers.

Table 14. — Average Annual Fixed, Operating, and Total Costs of 43 Heated-Air Drying Systems by Type of Fuel and Drying Structure, Illinois, 1954

	LP, column	Oil, column	Oil, bin	Oil, wagon
Number of driers	8	25	7	3
Drier investment[a]	$3,440	$3,270	$3,050	$2,600
Annual fixed cost[b]				
Drier	389.30	370.07	345.17	294.24
Fuel tank	21.94	8.13	8.13	8.13
Moisture tester	17.71	17.71	17.71	17.71
Electric wiring	15.18	15.18	15.18	15.18
Total	$ 444.13	$ 411.09	$ 386.19	$ 335.26
Annual operating costs[c]				
Fuel	$ 194.16	$ 220.65	$ 151.05	$ 130.95
Labor	48.60	37.80	22.50	30.60
Electricity	22.05	25.20	15.90	14.10
Repairs	12.72	11.80	8.87	8.10
Total	$ 277.53	$ 295.45	$ 198.32	$ 183.75
Total annual costs	$ 721.66	$ 706.54	$ 584.45	$ 519.01
Annual costs per 100 bushels				
Fixed	$ 4.26	$ 4.25	$ 5.31	$ 5.05
Operating	2.66	3.06	2.73	2.77
Total	$ 6.92	$ 7.31	$ 8.04	$ 7.82
Total bushels dried	10,430	9,670	7,270	6,640
Pounds of water removed per bushel	7.8	7.1	7.0	5.0

[a] Additional investment included $100 for fuel tank for oil, $270 for LP gas, $135 for a moisture tester, and $155 for electrical wiring.

[b] All groups of driers were depreciated over 13 years. Fuel tank, moisture tester, and electric wiring were depreciated over 20, 10, and 15 years, respectively. Other fixed costs were interest, 2.5 percent; taxes, 0.375 percent; insurance, 0.25 percent; and shelter, 0.5 percent of original investment.

[c] Fuel was charged at 15 cents per gallon for oil and 12 cents for gas; labor, 90 cents per hour; electricity, 2 cents per horsepower-hour of use; and repairs, $1.25 per 1,000 bushels. See Appendix Table 31 for total fuel, labor, and hours of machine use by groups of driers.

Electrical power costs amounted to 8 percent of the total operating costs (Table 15). The average cost for electric power for the four groups of driers ranged from 19 to 29 cents per 100 bushels. The average cost of this item for all driers was 24 cents per 100 bushels.

Major repairs included overhaul of electric motors and replacement of canvas ducts and fans. Minor repairs were replacement of thermostats, motor drive belts, fuel pumps, and filters. Lack of care and of preventive maintenance during the off-season was responsible for many of the repairs needed.

Repair costs, which included a charge for labor and a cash cost for parts and services, accounted for only 4 percent of the total operating costs (Table 15). The average cost was $1.25 per 1,000 bushels of corn dried. Repair costs per farm varied from zero to $112, but fewer than half of the farmers reported any repairs, largely because the average

Table 15. — Average Annual Operating Costs of Heated-Air Driers by Type of Fuel and Structure, Illinois, 1954

	LP, column	Oil, column	Oil, bin	Oil, wagon	Average	Percent of total
Operating costs per 1,000 pounds of water removed[a]						
Fuel	$2.38	$3.24	$2.97	$3.95	$3.14	74
Labor	.67	.50	.44	.66	.57	14
Electricity	.27	.37	.31	.42	.34	8
Repairs	.18	.18	.18	.18	.18	4
Total	$3.50	$4.29	$3.90	$5.21	$4.26	100
Operating costs per 100 bushels[b]						
Fuel	$1.67	$2.27	$2.08	$2.77	$2.20	74
Labor	.47	.35	.31	.46	.40	14
Electricity	.19	.26	.22	.29	.24	8
Repairs	.13	.13	.13	.13	.13	4
Total	$2.46	$3.01	$2.72	$3.65	$2.97	100

[a] Fuel was charged at 15 cents per gallon for oil and 12 cents for LP gas; labor, 90 cents per hour; electricity, 2 cents per horsepower-hour of use; and repairs, $1.25 per 1,000 bushels. See Appendix Table 31 for fuel and hours' machine use per 1,000 pounds of water removed by group of driers. Labor costs were based on average use per 100 bushels at 7 pounds of water removed per bushel.

[b] Costs per 100 bushels were adjusted on the basis of 7 pounds of water removed per bushel, the approximate average for all driers. See Appendix Table 31 for pounds of water removed by groups of driers.

age of the driers studied was only 3.0 years.[1] As the drying equipment assumes a normal age distribution, larger repair costs can be expected.

Annual fixed costs of drying included depreciation, interest on investment, taxes, shelter, and insurance.[2] Fixed costs represented from a half to two-thirds of the total annual costs of drying at volumes of 10,000 bushels, depending on the type of drier.

The fixed costs of operating a drier were primarily a function of investment and bushels dried, while operating costs were determined largely by the quantity of water removed per bushel. The effect of volume on average fixed costs per 100 bushels was shown by computing costs for quantities ranging from 2,000 to 28,000 bushels annually (Table 16).

The economy of the various groups of driers was influenced by fixed costs for the small volumes and by the operating costs at the larger volumes. Therefore, bin and wagon driers with smaller investments were the most economical at the low volumes (Table 16). The LP gas column driers and the bin driers had the lowest operating costs, and consequently, the lowest total costs at larger volumes.

Fixed costs for all drier groups decreased rapidly to an annual vol-

[1] See Appendix Table 31 for ages of driers by type.

[2] See Appendix E, "Method of Computing Fixed Costs of Drying."

Table 16. — Average Fixed and Total Drying Costs per 100 Bushels by Type of Fuel and Drying Structure, Illinois, 1954[a]

	LP, column		Oil, column		Oil, bin		Oil, wagon	
Number of driers	8		25		7		3	
Drier investment (average)	$3,440		$3,270		$3,050		$2,600	
Annual volume (bushels)	Fixed	Total	Fixed	Total	Fixed	Total	Fixed	Total
2,000	$22.20	$24.66	$20.55	$23.56	$19.30	$22.02	$16.76	$20.41
4,000	11.09	13.55	10.28	13.29	9.65	12.37	8.38	12.03
6,000	7.40	9.86	6.85	9.86	6.43	9.15	5.59	9.24
8,000	5.55	8.01	5.14	8.15	4.83	7.55	4.19	7.84
10,000	4.44	6.90	4.11	7.12	3.86	6.58	3.35	7.00
12,000	3.70	6.16	3.45	6.46	3.24	5.96	2.79	6.44
16,000	3.35	5.81	3.12	6.13	2.93	5.65	2.53	6.18
20,000	3.13	5.59	2.92	5.93	2.74	5.46	2.36	6.01
24,000	2.98	5.44	2.79	5.80	2.61	5.33	2.25	5.90
28,000	2.87	5.33	2.69	5.70	2.52	5.24	2.17	5.82

[a] Average variable costs were $2.46 for the LP gas column, $3.01 for the oil column, $2.72 for the oil bin, and $3.65 for the oil wagon-type driers. (See Table 15.) Fixed costs of drying were based on a 13-year obsolescence period or an expected life of 154,000 bushels, whichever was the limiting factor. Other fixed costs included interest, insurance, taxes, and shelter, totaling 3.625 percent of original investment. Fuel tank, moisture tester, and electrical wiring were charged at an annual cost of $54.83 for the LP gas column drier, and $41.02 for the oil column, oil bin, and oil wagon-type driers, respectively. (See Table 14.)

ume of 12,000 bushels. At this volume, the difference in fixed costs per 100 bushels between the LP gas column drier and the fuel oil wagon drier was only 91 cents.

Farm-drying versus market discounts. A farmer who does not provide for storage and sells the entire corn crop at harvest must decide whether he should sell high-moisture corn at a market discount or invest in drying equipment to avoid the discounts. The major factors to consider include (1) initial cost of drying equipment; (2) operating costs; (3) average moisture content before drying; (4) discounts for high-moisture corn; and (5) annual volume of corn to be dried.

Care must be exercised in manipulating the figures on pounds, percentages, dry matter, and discount rates involved in analyzing costs and gains on drying corn for direct marketing (Table 17). It is a common error to assume that the full difference between the discounted price and the basic bid for No. 2 corn is a loss to the farmer. For example, the discount for 22-percent corn is 21.5 cents a bushel. Drying the same bushel of corn to 15.5 percent results in a shrinkage in weight equal to 12.8 cents per bushel (includes 0.5 percent invisible loss) when No. 2 corn sells at $1.50 a bushel with 1.7 cents per bushel operating costs. The loss from selling corn with 22-percent moisture at a market discount as compared with drying it to 15.5 percent moisture equals the market discount minus the sum of shrinkage and operating costs: $21.5 - (12.8 + 1.7) = 7.0$ cents per bushel.

The break-even volumes serve as guides, but they must be carefully

interpreted if misleading conclusions are to be avoided. A farmer would have difficulty in making a drier pay if the average initial moisture content were below 20 percent (Table 17). Apparently, at high moisture levels, less than 2,000 bushels of corn are needed to make a drier profitable. Although this is true if the corn is sold at an average of 28- to 30-percent moisture, it does not represent a practical situation. Standing corn with a relatively high moisture content will lose an average of one-half of 1 percent of moisture per day. Thirty percent is about the upper limit for harvesting without excessive damage to kernels.

In most areas, there is seldom any necessity for harvesting small acreages at high moisture contents. Farmers can wait until the moisture content decreases by natural drying and still harvest ahead of hazardous weather and before significant field losses occur. A farmer with a large crop may begin to harvest with moisture near 30 percent, but it will probably be 20 percent or below before he finishes. The average moisture of corn coming from the field was 22 percent on the 77 farms included in this study. Thus the *basis for decision-making*

Table 17. — Break-Even Analysis for Selling High-Moisture Corn at Harvest Compared With Drying to 15.5 Percent Before Marketing

Moisture (percent)	Discount per bushel[a]	Loss from shrinkage (corn at $1.50)[b]	Operating costs[c] (per bushel)	Gain from drying[d]	Bushels to break even[e]	
					Wet corn	No. 2 corn
	cents					
30	60.5	26.5	3.3	30.7	1,400	1,200
26	40.5	19.4	2.4	18.7	2,400	2,100
24	30.5	15.8	2.1	12.6	3,500	3,200
23	25.5	14.1	1.9	9.5	4,700	4,300
22	21.5	12.8	1.7	7.0	6,300	5,800
21	17.5	10.5	1.5	5.5	8,100	7,500
20	13.5	8.7	1.2	3.6	12,300	11,700
19	10.5	7.0	1.1	2.4	[f]	[f]
18	7.5	5.2	.9	1.4	[f]	[f]
17	4.5	3.4	.8	.3	[f]	[f]
16	1.5	1.6	.6	−.7	[f]	[f]
15.5	0	0	0	0	0	0

[a] Discount was based on the schedule commonly used in Illinois in 1955: 15.6 to 20.0 percent moisture, 3 cents for each percent moisture; 20.1 to 23.0, 4 cents for each percent moisture; and above 23.0, 5 cents for each percent moisture.

[b] Shrinkage was calculated by the following equation: $\left[1 - \left(\frac{100 - \text{initial moisture}}{100 - \text{final moisture}} - .005\right)\right] \times$ basic bid for No. 2 corn.

[c] Operating costs were calculated at the rate of $2.83 per 1,000 pounds of water removed plus 47 cents per 100 bushels for labor for an LP gas column drier (Table 15).

[d] Gain from drying equals market discount minus the sum of shrinkage and operating costs.

[e] Total annual fixed cost of $444 for a LP gas column drier (Table 14) was used to compute break-even volumes of corn. Figures were rounded to nearest 100 bushels.

[f] Drying was impractical below 20-percent average moisture — regardless of volume, the gain from drying would not cover fixed costs.

lies in the relationships around the average moistures of *21 to 23 percent* for most farms, with the extremes seldom having any practical significance.

Although the price of corn and the discount schedules are both subject to change, the discount schedule is relatively less flexible than the price of corn. With a rigid discount schedule, drying is more favorable with low prices than with high prices for corn because the discount remains constant, while shrinkage reflects the change in the price of corn. In addition, it is assumed that corn can be dried exactly to 15.5 percent moisture to avoid a discount. Daily records of drying indicated that the controls and operating procedures used by the cooperators in 1954 did not permit such accuracy.

Marketing Part of Corn at Harvest

Frequently only a part of the corn is sold at harvest and the remainder is stored. If a drier is owned for use in storing part of the crop, the question is one of determining the moisture level at which it pays to dry corn for market rather than to sell at the discount price. In this instance, only operating costs of drying need to be considered — with labor included if it has an alternative use — because fixed costs are already committed. Thus, if the farmer can dry his corn and recover operating costs he is justified in drying it.

Assuming complete accuracy in drying to 15.5-percent moisture content, the net gain from drying corn with 18-percent moisture is 1.4 cents per bushel, and from corn with 17-percent moisture, 0.3 cents per bushel (Table 17). By overdrying one percentage point to 14.5 percent, there is an additional shrinkage cost of 2.4 cents per bushel plus the operating costs without any premium on price. Therefore, depending on accuracy of drying, it would normally not be practical to dry corn for market after it has reached 18- to 19-percent moisture content in the field.

Storage Costs of Shelled Corn

Most farms in Illinois have bin storage, which is used primarily for small grains. Therefore, a change from harvesting ear corn to field-shelling and drying requires construction of new bins or conversion of existing ear-corn storage or other buildings to storage for shelled corn.

Two basic costs are involved in storing shelled corn on the farm. First, the annual costs of the storage structure, including depreciation, interest on investment, taxes, and maintenance and repairs. Second, the farmer incurs costs for holding the grain rather than selling at harvest. These costs include interest, insurance, and taxes on the grain. There

are additional costs for extra handling, insect control, and possible shrinkage and quality loss. In some years, the farmer may have a cost because of an unfavorable price change.[1] The net effect of the various costs for holding the grain remain constant among different types of storage, assuming that all structures are suitable for holding grain. Computation of costs, therefore, was limited to a comparison of structural costs of different types of buildings for shelled corn.

The annual structural costs of storing shelled corn on the farm vary according to (1) differences in original cost of structure; (2) size; (3) extent of utilization; and (4) length of life. The effect of these factors on costs is shown in Table 18.

Circular metal bins were the least expensive for small volumes of corn. The initial investment for metal bins ranged from 55 cents to 34 cents a bushel for capacities of 1,000 to 3,750 bushels (Table 18). Concrete stave silos were the least expensive for the large volumes — 60 cents to 28 cents a bushel for capacities of 2,000 to 10,000 bushels. Airtight bins ranged from 88 cents to 68 cents a bushel for capacities of 4,700 to 9,200 bushels.

The initial costs of the three types of structures ranged from 88 cents to 28 cents a bushel. In general, however, the size of structure and degree of utilization had more effect on the total annual cost per bushel than the type of structure.

Converting Ear-Corn Cribs and Other Buildings

Most farmers who are considering the change to field-shelling and drying have some storage facilities on the farm; therefore, they must decide whether to convert these facilities or build more structures. The advisability of converting ear-corn cribs and other buildings to storage for shelled corn can be examined from two types of costs — initial investment and annual costs.

The initial investment for converting ear-corn cribs to storage for shelled corn was reported by 6 of the farmers included in the study. Their costs, which included materials and labor, ranged from 5 to 22 cents per bushel. If estimated conversion costs are as high as 25 cents per bushel, new structures should be considered.

A more practical basis for the decision to remodel may be annual costs. Even if the converted structure has an initial conversion cost lower than the cost of a new structure, the higher rate of depreciation and probable need for more extensive repairs may result in a more expensive storage structure from the standpoint of annual costs.

[1] Norton, L. J. When to Market Grain. Ill. Agr. Ext. Cir. 711. 1953.

Table 18. — Ranges of Initial Construction and Annual Ownership Costs of Steel Bins, Concrete Silos, and Airtight Bins of Various Capacities, 1956[a]

Rated capacity	Size	Initial cost of materials, foundation, and labor[b]		Annual fixed costs per bushel[c]		
		Total	Per bushel	100 percent full	75 percent full	66 percent full
bushels	*feet*	*dollars*	*dollars*	*cents*	*cents*	*cents*
		Circular steel bins				
1,000	14 × 8	490–550	.49–.55	4.1–4.6	5.5–6.1	6.2–6.9
2,150	18 × 10½	860–920	.40–.43	3.4–3.6	4.5–4.8	5.0–5.4
2,950	18 × 14½	1,090–1,130	.37–.38	3.1–3.2	4.1–4.2	4.6–4.8
3,350	18 × 16½	1,140–1,220	.34–.36	2.8–3.0	3.8–4.0	4.3–4.5
3,750	18 × 18½	1,290–1,370	.34–.36	2.8–3.0	3.8–4.0	4.3–4.5
		Concrete stave silos				
2,000	12 × 22½	990–1,190	.50–.60	3.3–4.0	4.4–5.3	4.9–5.9
4,000	14 × 32½	1,490–1,830	.37–.46	2.5–3.1	3.3–4.1	3.7–4.6
6,000	16 × 37½	1,910–2,310	.32–.39	2.1–2.6	2.9–3.5	3.2–3.9
8,200	18 × 40	2,390–2,670	.29–.33	1.9–2.2	2.6–3.0	2.9–3.3
10,000	20 × 40	2,780–3,130	.28–.31	1.9–2.1	2.5–2.8	2.8–3.1
		Airtight bins				
4,700	14 × 40	4,155	.88	5.9	7.9	8.8
6,800	17 × 40	5,020	.74	5.0	6.6	7.4
9,200	20 × 40	6,270	.68	4.6	6.1	6.8

[a] The range in costs was based on 1956 prices from 5 companies for steel bins and 2 companies for concrete stave silos.

[b] Costs include all materials, delivery costs, and labor for foundation construction and erection of structure. Foundation costs were based on $15 per cubic yard of concrete and labor at 60 percent of the cost of materials. Estimated foundation costs for the steel bins were $140 for the 14-foot bin and $200 for the 18-foot bin. Foundation costs for the concrete stave silos were $170, $210, $250, $290, and $330 for the 12-, 14-, 16-, 18-, and 20-foot-diameter structures, respectively. Costs for the air-tight bins were $275, $350, and $425 for the 14-, 17-, and 20-foot bins, respectively.

[c] Depreciation costs were based on an expected life of 20 years for the steel bins and 30 years for the concrete silos and airtight bins. Other fixed costs include interest at 5 percent, insurance at 50 cents per $100 valuation, taxes at $2.25 per $100 valuation (one-third replacement costs) and maintenance at one-fourth of 1 percent.

Costs of Field-Shelling Compared With Those of Conventional Picking Method

A cost analysis that assumes the corn is to be harvested and stored on the farm for feed or future sale is applicable to most Illinois farms. Annual costs per bushel for two harvesting methods and for three different volumes of corn are presented in Table 19. All facilities and equipment were assumed to be new. A charge was made to the ear-corn method for additional field losses in order to adjust the costs for a difference in time of harvesting. At 6,000 bushels annually, the conventional ear-corn method of harvesting was less expensive than field-shelling and drying. At the larger volumes of 10,000 and 14,000 bushels, however, field-shelling became the least expensive method.

The advantages of field-shelling and drying were indicated by lower hauling and unloading costs, much lower storage costs, and fewer field losses because of earlier harvest. These advantages were offset at the small volume by the high costs of drying. In figuring costs for field-shelling, the self-propelled field sheller was used as typical equipment. The power unit of the self-propelled field sheller was a special-purpose machine and was not used as many hours as the tractor. This unit was limited in use on most farms to the harvesting of corn, soybeans, and small grains, which, at low volumes, caused the average fixed costs to be high.

Storage of High-Moisture Shelled Corn in Airtight Bins

Storage of high-moisture shelled corn in airtight bins is an alternative to drying if the corn is to be fed on the farm.[1] Six farms were studied on which airtight bins for storage were used. These farms were located in Boone, DeKalb, and Ford counties (Figure 1), and specialized in livestock, each farm averaging 175 beef steers and 167 feeder pigs. During 1953 and 1954, 99 percent of all corn produced was fed to livestock. Two of the farms were owner-operated, 3 were operated by part-owners, and 1 was a manager-operated farm. The farms averaged 413 acres in size, with 395 tillable acres and 184 acres of corn.

Farmers gave the following reasons for making the shift to field-shelling and storage in airtight bins: (1) shortage of storage; (2) pre-

[1] All airtight bins observed were "Harvestores" manufactured by A. O. Smith Corporation, Kankakee, Illinois. The spoilage of high-moisture grain is due primarily to micro-organisms. Exclusion of oxygen from storage grain reduces this cause of grain spoilage. For further details, see "Effects of Corn Storage in Airtight Bins" by G. H. Foster, H. A. Haler, and R. L. Whistler, Agricultural and Food Chemistry, vol. 3, p. 682. 1955.

Table 19. — Average Total Costs for Harvesting and Storing Ear Corn Compared With Those for Field-Shelling, Drying, and Storing Shelled Corn for Different Volumes

	Bushels of corn picked and stored			Bushels of corn field-shelled, dried and stored		
	6,000	10,000	14,000	6,000	10,000	14,000
	cents per bushel					
Harvesting[a]	6.5	5.1	4.6	9.9	7.0	5.9
Hauling and unloading[b]	3.2	3.2	3.2	2.5	2.5	2.5
Drying[c]	...	...	...	9.9	6.9	6.0
Storing[d]	8.4	7.7	6.7	2.9	2.9	2.9
Shelling	2.5	2.5	2.5	...	...	...
Field loss[e]	3.0	3.0	3.0	...	...	...
Total	23.6	21.5	20.0	25.2	19.3	17.3

[a] Harvesting costs were computed for the self-propelled field sheller and the picker (Table 11). A charge for labor of 90 cents per 100 bushels was made for picking.

[b] See Table 13 for hauling and unloading costs for shelled corn. Costs for ear corn were estimated to be a third greater than for shelled corn.

[c] Drying costs were computed for the LP gas column batch drier (Table 16).

[d] Costs of storage were computed for the circular metal bins for the field-shelling method (Table 18). Ear-corn storage costs were based on initial investment costs per bushel of $1.25, $1.15, and $1.00 for the three volumes in order of increasing number of bushels.

[e] A charge of 2 percent of gross yield was made for greater field losses.

ferred high-moisture shelled corn for feed; (3) less labor required in handling the corn from the field to the feedlot; (4) protection against soft corn; and (5) lower field losses because of earlier harvest. Two of the farmers did not field-shell the total corn crop because of a shortage of storage for shelled corn. One farmer who had good ear-corn storage wanted some ear corn to grind and mix with the shelled corn for feed.

On the farms studied, the moisture content of the corn stored averaged 22.5 percent, and ranged from 30 to 18 percent. At high moisture, some of the corn was cracked and damaged as it was blown into storage and as it was removed. Apparently, however, the feeding value was not affected.

The equipment for field-shelling and hauling was the same as that used in the drying operation. The bins were usually filled by a tractor-powered forage blower. The airtight bins were constructed with an unloading pit at the bottom and equipped with a heavy-duty silage-type unloader.

The initial investment in equipment and structures for harvesting and storing corn in airtight bins was higher than that for field-shelling, drying, and storing in concrete stave silos, but annual costs were lower (Table 20). However, the advantage of lower annual costs was partially offset by loss of opportunity to market the corn.

Table 20. — Average Total Costs per Bushel for Field-Shelling and Storing High-Moisture Shelled Corn Compared With Those for Drying and Storing in Concrete Silos, Illinois, 1954

	Bushels of corn artificially dried and stored		Bushels of high-moisture corn stored in airtight bins	
	6,800	9,200	6,800	9,200
	cents			
Field-shelling[a]	9.4	7.7	9.4	7.7
Hauling and unloading[b]	2.5	2.5	2.5	2.5
Drying[c]	9.0	7.3	...	...
Storage[d]				
Concrete stave silo	2.2	2.0	...	...
Airtight bin	...	...	5.0	4.6
Unloader[e]	...	...	3.1	2.5
Total	23.1	19.5	20.0	17.3

[a] Field-shelling costs were computed for a self-propelled picker-sheller. Operating costs for labor, fuel, repairs, and maintenance were charged at 2.9 cents per bushel (Table 12).

[b] Hauling and unloading costs, including power, equipment, and labor costs, were the same for both methods (Table 13).

[c] Drying costs were computed for a column batch-type drier using LP gas and removing 7 pounds of water per bushel. Operating costs for labor, fuel, power, and repairs amounted to 2½ cents per bushel (Table 16).

[d] Only average annual fixed costs of storage were included. Variable costs were assumed to be similar with both types of structures (Table 18).

[e] A standard heavy-duty cutter-arm unloader was used with high-moisture shelled corn.

Landlord-Tenant Arrangements for Sharing Costs

Twenty-four tenant operators reported 14 different combinations of ownership of equipment and methods of distributing costs of operation (Table 21). The most common arrangement was for the tenant to own the harvesting equipment and the landlord to own the storage structures. Ownership of the drying equipment was about equally divided.

Operating costs for field-shelling were distributed in three ways: (1) the tenant and landlord shared the costs equally; (2) the costs were paid by the tenant; and (3) the landlord paid the tenant 2 to 3 cents a bushel for shelling. Operating costs for drying were usually shared 50-50.

The wide differences in methods of sharing costs and ownership among these farmers reflect a lack of knowledge of costs and of what constitutes a fair sharing of costs. The few parent-son leases may explain the extreme range from complete ownership by the tenant to complete ownership by the landlord. Studies of landlord-tenant leases indicate that because of the many cost-sharing situations in the leases all of the variations shown could be equitable.

Table 21. — Ownership and Distribution of Costs of Field Shellers, Heated-Air Driers, and Storage Structures on 24 Illinois Tenant Farms, 1954[a]

Number of farms	Field shellers		Driers		Ownership of storage
	Ownership of equipment	Cost sharing	Ownership of equipment	Cost sharing	
5	Tenant	50–50	Landlord	50–50	Landlord
4	Tenant	Tenant	Tenant	Tenant	Landlord
2	Tenant	Tenant	50–50	50–50	Landlord
2	Tenant	50–50	50–50	50–50	Landlord
2	⅔–⅓[b]	50–50	⅔–⅓[b]	50–50	⅔–⅓[b]
1	Tenant	Tenant	Tenant	50–50	Tenant
1	Tenant	Tenant	Tenant	50–50	Landlord
1	Tenant	Tenant	Landlord	50–50	Landlord
1	Landlord	Tenant	Landlord	50–50	Landlord
1	Tenant	.02 per bu.	Tenant	.02 per bu.	Tenant
1	Tenant	.02 per bu.	Tenant	.07 per bu.	Tenant
1	Tenant	.02 per bu.	Landlord	50–50	Landlord
1	Tenant	.03 per bu.	Tenant	50–50	Landlord
1	Tenant	.03 per bu.	50–50	50–50	Landlord

[a] All costs in cents per bushel represent payments by the landlord to the tenant for field-shelling or drying the landlord's share of the crop.
[b] Tenant paid ⅔, owner ⅓.

A fair sharing of costs depends upon the type of equipment, the storage structures, and the volume of corn. In most instances, the tenant should own the harvesting, hauling, and unloading machinery and equipment, and the landlord should own the storage structures and drier. Then a 50-50 sharing of harvesting and drier fuel tends to equalize total costs.

MARKETING IMPLICATIONS

At the beginning of this study, primary interest was in the management and cost problems involved in the shift to field-shelling and artificial drying of corn. Information obtained during the study, however, indicated that the potential effects on the marketing of corn were also important.

Based on an estimated 175 driers in Illinois and the average volume of corn marketed per farm,[1] it is estimated that 1,250,000 bushels of artificially dried corn moved into the "cash-corn" market in Illinois in 1954. This volume of corn represented less than 0.5 percent of all corn marketed in Illinois. At present the quantity of corn artificially dried is negligible. However, an increase in the adoption of field-

[1] See Appendix Table 27 for volume of corn marketed by farm.

sheller-drier methods of handling corn may create difficulties for wet millers and the grain trade in general.

Corn has four major categories of use: seed, export, food and industry, and livestock feed. In contrast to soybeans and wheat, corn is primarily a feed crop. The five-year average of corn utilization in the United States, 1949-1953, shows that livestock feed accounted for 88 percent of total corn production, while food and industrial uses[1] represented only 8 percent of total corn production.[2] Yet the latter is one of the most important outlets for corn sold off farms in Illinois.

About 25 percent of all corn produced in the United States is sold from the farms where it is produced. Approximately 45 percent of all Illinois corn is sold, and the percentage is even higher in the chief corn-growing areas.[3] Therefore, a harvesting method that might affect market grades or the quality of corn for feed or nonfeed uses may have important implications in the major corn-producing areas.

Quality of Field-Shelled and Artificially Dried Corn

During the 1954 harvest, samples of corn were taken on 29 farms to get an indication of the physical quality of corn field-shelled and artificially dried. Samples were harvested by all three types of field-shelling machines. Moisture before drying ranged from 32 to 16 percent. Composite samples were obtained with a standard grain probe from both high-moisture and dry corn. Samples were weighed and then graded by picking out the trash by hand and screening the cracked corn through a 10/64-inch screen. Trash and cracked corn were weighed to determine percentages. The quantity of cracked corn ranged from 0.1 to 2.5 percent and trash ranged from 0.1 to 2.6 percent. The averages were 0.8 percent for cracked corn and 0.3 percent for trash.

Corn shelled at moistures of 30 percent and above contained more cobs and shucks than corn harvested at lower moisture contents. The high-moisture corn also contained considerably more broken and chipped kernels. Below 26- to 28-percent kernel moisture, the adjustment of the field sheller, type and number of conveyors, and the drying system were the major factors that affected the physical quality of market corn.

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[1] Includes dry milling, wet milling, breakfast foods, alcohol, and distilled spirits.

[2] Percentages based on data in Feed Situation, U. S. Dept. Agr., Agr. Market. Serv., p. 7, July 29, 1955.

[3] U. S. Dept. Com. Bur. Census, U. S. Census of Agriculture, 1950, vol. 1, part 5. 1952.

Although the system of grading used in the analyses cannot be used for comparison with official grade requirements, it is believed that only 3 of the 29 samples would have graded below No. 2 corn.[1] The 3 samples were taken from operations involving unusual field-shelling and drying conditions.

One sample of corn was harvested in a field that had been covered with water. Even after drying and handling, the corn was still quite dirty. Another sample of corn had been dried twice, and an oil film had been deposited on the grain by combustion gases from the direct-heat, oil-burning heating unit. A third sample had been field-shelled at 32-percent moisture content; it contained 6.3 percent split or broken kernels. Thus, on the basis of observation and graded samples, the physical quality of corn field-shelled and dried below 30-percent moisture was good, except for a few unusual circumstances.

No significant differences in quality of shelled corn were found among the three types of field shellers. Differences were greater within the groups representing a single type of machine than among the three types of machines.

Farmers' Experiences in Marketing

Farmers who marketed artificially dried corn received some discounts and met occasional resistance from elevators in the sale of corn. One farmer who field-shelled at 34-percent moisture received a 3-cent discount per bushel for cracked corn. Another received a 1-cent discount for excessive cobs. A third farmer received a discount for an objectionable foreign odor that developed because the high-moisture corn had been left in storage for a day before drying. Warm weather and high-moisture content had caused the corn to heat and start to sour. The corn was dried but the odor was not eliminated. In all three instances, the corn was field-shelled at moisture contents in excess of 30 percent.

Comments received from a storage-and-marketing questionnaire in 1955 indicated that no farmers were unable to sell their artificially dried corn. One farmer reported that some of the elevators wanted to discount his corn; as a result he went to several elevators before making the sale. Even then he had to sell some ear corn at the same time to obtain the regular price. Another report concerned dustiness and fine

[1] United States Department of Agriculture grade requirements for grade No. 2 shelled yellow corn are (1) minimum test weight of 53 pounds per bushel; (2) maximum limits of 15.5-percent moisture content, 3 percent cracked corn and foreign material, 5 percent total damaged kernels, 0.2 percent heat-damaged kernels.

material in the corn. The elevator operator claimed that if the corn were sold in carload lots, it would not pass the grain tester without discount because of dustiness. The dustiness usually resulted from improper shelling at excessive moisture contents — 30 percent and above.

Artificially Dried Corn for Feed

Some livestock feeders believed that artificially dried corn was too hard to feed to cattle and hogs without cracking or crimping. This comment was most commonly made by farmers who feed beef cattle. One farmer reported that at weights above 150 pounds, his hogs ate an excess of protein supplement rather than the dried shelled corn.

These reports reflect the need for research involving nutritional and feeding qualities of artificially dried corn as compared with other methods of handling corn. One such research study has been conducted and reported.

In November, 1954, animal scientists at the University of Illinois began a 126-day feeding trial in which they used two lots of heavy, choice feeder calves. In this test, one lot was fed a ration that included corn harvested at 30-percent moisture and dried at 180° F. to 16-percent moisture. Similar corn that had been field-dried to 16-percent moisture before harvesting was shelled and stored for comparative purposes. Under the conditions of this test, no significant difference was found either in rate or cost of gain.[1]

Effect of Drying on Quality of Corn Used in Wet-Milling Industry

At present, there is no certain way to determine the extent of damage of excessive drying temperatures on the milling quality of corn until the corn goes into the milling process. The importance of this problem was expressed by Dr. R. E. Greenfield of A. E. Staley Company, Decatur, Illinois, in a talk before the 1955 Illinois Farm and Home Week audience. Dr. Greenfield stated:

> Many years ago the milling industry found that it just was not able to handle corn which had been dried by the usual commercial drying practices. The result is that our industry as a whole has been very opposed to buying dried corn at all. It is not a matter of discount: we simply do not want the material at all because it cannot be handled.

[1] Albert, W. W., and Neumann, A. L. Study of the Effect of High-Temperature Drying of High-Moisture Field-Shelled Corn When Fed to Beef Steers. Univ. Ill. Dept. An. Sci. AS430h (mimeo), pp. 1-2. 1955.

> Undoubtedly many commercial driers of corn can and do produce corn which would be satisfactory for our use but here the second difficulty imposes itself. We have no way of telling . . . whether the corn has been dried at a temperature high enough to damage it so that we can detect it and reject it before it goes into our process.[1]

Dr. Greenfield also pointed out that the corn-refining industry consumed from 20 to 30 percent of all corn sold off farms and nearly 50 percent of all corn used for nonfeed uses. He stated further that the growing use of picker-sheller-drier combinations may create problems in selling corn to the milling industry that would affect the entire cash-corn market unless accurate and reliable drying controls could be developed. To meet this situation, wet millers buy in areas or from local elevators where they can be assured of getting naturally dried corn. As far as wet millers are concerned, artificial drying of corn is not altogether a farm problem — some local elevators also dry corn artificially.

It is generally recommended that drying temperatures be kept below 130° F. to prevent damage to milling quality. Daily records of 43 heated-air driers in 1954 indicated that most farmers use higher temperatures in order to maintain a faster drying rate. The average temperature of the drying air for all driers was 148° F., with a range of 120° to 190° F.[2]

Time of Marketing

One advantage commonly listed for field-shelling and drying is the possibility of a premium price for dry corn or of selling new corn at prices paid for old corn. During the 1954 season, some farmers were able to field-shell and dry early enough to sell new corn at the same price as old corn. This opportunity does not occur every year, and when it does occur, not all farmers or elevators are able to take advantage of the situation. Some local elevators do not like to handle corn when they are busy receiving soybeans. Capacities and facilities, especially with the small elevators, may not be sufficient to handle the two crops at one time. Elevators that do not have the facilities to blend corn may not realize any gain from handling dried corn. A substantial increase in the volume of corn marketed at harvest could result in a penalty rather than a premium during this period.

[1] The complete text of this speech was reproduced in the January, 1955, issue of "Current Information for the Staley Foreman."

[2] See Appendix Table 31 for a summary of drying temperatures by type of drier.

An increase in field-shelling and artificial drying may change the seasonal pattern of marketing. From 1949 through 1954, monthly marketings of corn in Illinois averaged 13 percent in October, 14 percent in November, and from 6 to 8 percent in each of the remaining ten months. The major burden of financing and storing market as well as feed corn has obviously been carried by farmers. During these same years, 64 percent of soybean crops were sold from September through November, with 40 percent in October. Eighty percent of the Illinois wheat crop was sold in July.[1]

A continued increase in field-shelling and artificial drying may cause a change in seasonality of both corn prices and quantities marketed. A much higher percentage of the corn crop may be sold at harvest, thus causing more of a peak pattern of marketing. And if the early marketing of corn is increased, the usual break in the price of corn would be likely to come earlier.

Illinois farmers produced 100 million bushels of soybeans and 51 million bushels of wheat in 1955. Practically all of these two crops were sold. Production of Illinois corn for 1955 was 524 million bushels,[2] and about half of the crop went to market.

Even small increases in the proportion of corn sold during harvest would put an extra burden on the already overloaded storage and transportation facilities of the grain trade. The competition of corn and soybeans for marketing facilities during September and October could result in serious complications. One possible outcome of a greater concentration of corn marketing in a given month would be a greater seasonal price differential to induce farm storage. Expansion of facilities within the grain trade is also a possibility. This expansion could result in a shift to corn stored and conditioned by the grain trade rather than on the farm.

SUMMARY

Field-shelling, artificial drying, and farm storage of shelled corn were studied on 77 Illinois farms during the 1954 and 1955 harvesting seasons. Six additional farms on which high-moisture corn was field-shelled and stored in airtight bins were included. The complete harvesting process was studied from the viewpoint of integration into the farm business and to determine the economic and managerial implications of the change in harvesting method.

[1] Illinois Agricultural Statistics, Annual Summary 1955, Ill. Dept. Agr. and U.S. Dept. Agr. Bul. 55-1, pp. 26-33, 1955.

[2] According to the annual crop summary issued by the Illinois Cooperative Crop Reporting Service, December 23, 1955.

The farms studied were located in central and northern Illinois; averaged about 400 tillable acres and 184 acres of corn; were about equally divided between grain and livestock farms; and included all systems of tenure. Field shellers were pull-type and self-propelled picker-shellers and ear-corn pickers with trailing shellers. Pull-type machines were the most numerous. Although various makes and types of heating units were used, most of the units were fuel oil direct-heat burners. About three-fourths of the drying structures were batch column-type structures. New storage structures were nearly all circular steel bins and masonry silos.

The principal reasons farmers gave for making the shift to shelled-corn methods were shortage of storage space and cheaper storage for shelled corn, easier work, and reduction of field losses. The shift to harvesting of shelled corn was incomplete on more than a third of the farms in 1954.

Differences were unimportant among types of field shellers with respect to field losses, quality of corn, and rate of harvesting. Reduction of field losses through earlier harvesting and relatively low travel speed were the most significant economic effects of using field shellers.

From the standpoint of both management and costs, drying was the critical part of the harvesting operation. Heated-air drying, a new operation, involved technical relationships with which farmers were not familiar. As a result, they had to learn by experience, frequently at the expense of underdrying, overdrying, or overheating corn.

The most effective field-shelling, artificial drying, and storage operations were integrated into the farm operation with respect to layout of drying and storage facilities, effect on feed processing and handling, feeding systems, and available labor. In the complete process of field-shelling, drying, and storing corn, the requirements for man-and-machine time changed from the beginning to the end of the season, regardless of system and type of equipment. Complete utilization of all man-and-machine time occurred for only a few days during the harvesting season and was influenced primarily by the size of crew, the type of field-shelling and drying equipment, and the moisture content of the corn.

A 2-man crew represented the most practical and efficient use of man-and-machine hours over the entire harvesting season. This size of crew normally had sufficient time to carefully check and supervise the drying operation. Too much delay and free time occurred with a 3-man crew unless the free time was used for livestock chores or other work.

With a 1-man crew, any unusual trouble stops or difficulties in the coordinated plan of all operations threw the complete harvesting process out of balance and caused serious delay. At the beginning of the season, the 1-man crew was limited by the machine-drying time, and the tendency was to accelerate the drying job. Consequently, corn was likely to be stored at an excessive moisture content, and at too high a temperature. As man-hours became critical at the end of the season when the moisture content was low, the 1-man crew reduced field-shelling time by increasing machine speed and cutting down the time used in checking and supervising the drying operation. The results were increased field losses and possible overdrying of the corn.

Total field-shelling costs were highest for the picker-and-sheller at all volumes and least for the pull-type machine for volumes up to 18,000 bushels. Above this volume, the self-propelled machine was the most economical. For an annual volume of 10,000 bushels, total field-shelling costs per 100 bushels were $6.20, $6.99, and $8.46 for the pull-type picker-sheller, self-propelled picker-sheller, and picker-and-sheller machine, respectively. Fixed costs represented about two-thirds of the total costs. Labor was the largest operating cost of field-shelling.

Labor and equipment costs to move the corn from the field and unload it into the drier amounted to $2.55 per 100 bushels. This figure was computed on the basis of one third allocation of the cost of equipment — wagons, conveyors, and lifts — to the corn enterprise.

On the average, annual drying costs were about the same as field-shelling costs for comparable volumes. The economy of the different groups of driers was influenced more by fixed costs for small volumes and by operating costs at larger volumes. At 10,000 bushels' annual volume and 7 pounds of water removed per bushel, total drying costs per 100 bushels only varied from $6.58 for the bin-type drier to $7.12 for the column-type drier. Fixed costs represented from a half to two-thirds of the total annual costs of drying at volumes of 10,000 bushels, depending on the type of drier. Fuel was the largest item of operating costs and accounted for about three-fourths of total operating costs.

New storage for shelled corn included circular metal bins, masonry silos, arched-roof steel buildings, and an occasional wooden bin. Circular metal bins of 3,300 to 3,750 bushels' capacity were the most popular and the least expensive for small volumes. Initial investment ranged from 55 cents to 34 cents a bushel for capacities of 1,000 to 3,750 bushels. Concrete stave silos were the least expensive for large volumes, with a range in initial investments of 60 cents to 28 cents a bushel for capacities of 2,000 to 10,000 bushels.

A comparison of field-shelling and drying and conventional picking and storing indicates that a farmer should handle a minimum of 7,000 to 7,500 bushels of corn annually before considering the shift in harvesting method. On a purely cash-grain and market basis, a farmer would need to dry 5,800 bushels of No. 2 corn at an average moisture content of 22 percent to save enough on market discounts to pay for the drying.

Two-thirds of a group of 57 farmers reported storage difficulties with their 1954 corn. These difficulties included crusting, spoilage, heating, and insect infestation. Most of the problems were the result of failure to store clean corn or to dry the corn to low enough moisture content. Conditioning equipment is necessary for safe storage of shelled corn on the farm.

As an alternative to drying, high-moisture shelled corn may be stored in airtight bins. This method, which has the advantages of lower annual costs and fewer management problems, was frequently used in large-scale feeding operations for beef cattle.

The marketing implications resulting from increased field-shelling and artificial drying of corn are of mutual concern to farmers, machinery manufacturers, the milling industry, and the grain trade. Based on observation and graded samples, the physical quality was generally good for corn that was field-shelled and dried below 30-percent moisture content. A few farmers met resistance and received penalty discounts in selling their dried corn because of excessive cracking, too many cobs, and unpleasant odor.

Some livestock feeders, particularly cattle feeders, reported that artificially dried corn was too hard to feed to cattle and hogs without cracking or crimping. This problem was most frequently mentioned by cattle feeders. However, limited feeding trials in which artificially dried corn was used have not indicated any significant reduction in the feeding value.

Wet millers and other corn processors do not want corn dried with heated air. At present, they have no way of determining the extent of damage of excessive drying temperatures on milling quality until the corn gets into the milling process.

The rate of adoption of shelled-corn methods will depend greatly on replacement needs for storage and mechanical pickers. Improvements in the operational efficiency of field shellers and heated-air driers — especially the latter — are needed to reduce costs and to make the shift to field-shelling and artificial drying more feasible economically.

Areas in which further research and extension work are needed include the following:

1. Design of field shellers to further reduce field losses and damage to kernels at high-moisture content.
2. Design of driers with controls to permit greater accuracy and increase speed in drying to specified moisture levels.
3. Effect on feeding and milling qualities of corn field-shelled and dried with heated air at various moisture contents and drying temperatures.
4. Potential effect of an increased volume of shelled corn marketed during harvest, including both high-moisture corn direct from the field and corn artificially dried.
5. Appropriate cost-sharing arrangements between tenants and landlords, custom rates of drying, and farm layouts of equipment and storage structures for typical farm organizations.
6. Work with farmers in integrating the shelled-corn method into the farm operation, including information on the frequent management difficulties inherent in the complete harvesting process.

(Appendix A)

ESTIMATING FIELD LOSSES

Counts of kernels and ear corn were made in at least four areas of the field. These areas were selected at random and on rows that represented both directions of machine operation. Losses of shelled corn were estimated by counting kernels in 40-inch squares. Twenty kernels in a square represented a loss of one bushel per acre. Ear losses were estimated by counting ears in 133 feet of row, each good-sized ear (¾ of a pound) representing a loss of one bushel per acre.

A minor limitation of this method was that total losses of shelled corn could not be separated accurately into losses from snapping rolls and losses from the sheller. Kernels left on cobs were obviously sheller losses and were counted separately. Except for a few instances of corn with very high moisture, the number of these kernels was small. Observation of cobs and husks coming from the sheller indicated that the number of loose kernels lost at this point was unimportant.

In some instances, there was a noticeable difference in losses from snapping rolls on the two rows harvested at the same time. This variation was caused by differences in adjustment and condition of the two sets of snapping rolls.

(Appendix B)

WEATHER CONDITIONS BEFORE AND DURING HARVESTING SEASON, ILLINOIS, 1954[1]

Rainfall and weather in general before harvest varied in different parts of the state. The southern and central areas had drouth or semi-drouth conditions, while rainfall was above normal in the northern areas. These conditions caused a difference in yields of corn and in the time at which corn was mature enough for harvest.

During the last 65 years, only two other Septembers have been warmer and drier than September of 1954. The latter part of the month was mild, with maximum temperatures in the high seventies in the north and in the low eighties in the south.

October was wet and cloudy, with unusually warm temperatures early in the month. Above-normal temperatures were the rule during the first half of the month, with warm periods from the first to the fourth, the eighth to the thirteenth, and the twenty-second to the twenty-sixth. On the third, temperatures of 90 degrees and above were recorded at most stations. Below-normal temperatures prevailed during the last half of the month, with cooling periods from the fourteenth to the twentieth and the twenty-seventh to the thirty-first.

Early in the month general rains slowed harvesting, particularly in the north. On October 9 to 11, 1954, northern Illinois had a severe storm and deluge that resulted in the greatest flood disaster in the history of Chicago and nearby communities to the south and west. Later periods without rainfall permitted harvesting to proceed rapidly except in the north, and by the end of the month, 78 percent of the corn had been picked.

November was mild, with less than half the normal rainfall. The cool weather that began on October 27 continued until November 5. Warmer-than-normal weather prevailed for the next two weeks, with normal temperatures during the latter part of the month. Ninety-five percent of the corn was harvested by the fifteenth, and by the end of the month, only a few fields remained unpicked.

[1] U. S. Dept. Com. Weather Bur. Climatological Data, Illinois, vol. 59, pp. 104, 116, and 128. 1954.

(Appendix C)

DEFINITIONS OF FIELD-SHELLING, HAULING, UNLOADING, AND DRYING OPERATIONS, BY JOBS

Field-Shelling

To rows — time from end of one row to start of field-shelling on next row; time to or from storage wagon.

Field-shell — actual operating time for machine.

Trouble stops — forced stops during picking for repair, adjustment, checking and cleaning.

Unload or change wagons — unloading full tank into storage wagon or exchanging full wagon for an empty one.

Maintenance — check, adjust, clean, or grease field sheller during stops other than forced stops.

Delay — any time lost because of jobs in the harvesting process other than field-shelling.

Hauling and Unloading

Drive — round trip from first stop at drier to first stop in field.

Prepare to unload — all work elements for getting ready to put a load of wet corn into the drying chamber or a wet-corn storage bin.

Unload — all work elements involved in elevating corn into drying chamber or wet-corn storage bin.

Trouble stops — breakdown of hauling and unloading equipment.

Load or change wagons — work elements involved in exchanging an empty wagon for a full wagon, and all driving from a parking area to the field sheller to receive grain tank load, including following field sheller around the field.

Delay — any lost time because of jobs in the harvesting process other than hauling and unloading.

Drying

Fill drying chamber — all work elements associated with moving wet corn from storage into drying chamber; corn unloaded directly from wagon into drying chamber is considered unloading and is not counted in this operation.

Check and supervise — all work elements associated with actual operation of the drier, including leveling corn, taking samples and testing, and supervision if an operator remains with the machine.

Empty drying chamber — all work elements associated with move-

ment of dry corn from the drier into storage, or hauling trucks or wagons for market.

Delay — any time lost because of jobs in the harvesting process other than drying.

(Appendix D)

METHOD OF COMPUTING FIXED COSTS OF FIELD-SHELLING

The expected life for each type of field sheller, as determined from farmers' estimates of the remaining life of their equipment, was inversely associated with the number of acres of corn harvested. Farmers with low acreages of corn tended to limit their estimates to a 10-year life because of obsolescence. Some farmers who had small acreages of corn or were using new equipment for the first or second year did not make positive estimates.

The estimated expected life of field shellers as reported by 23 farmers is summarized below:

	Picker-sheller		*Picker and sheller*	*All machines*
Less than 10 years' expected life	*Pull-type*	*Self-propelled*		
Number of estimates	4	3	3	10
Average:				
Years	7.2	7.0	7.7	7.3
Acres	230	270	270	250
Expected life:				
Acres	1,660	1,890	2,080	1,860
Hours[a]	1,490	1,700	1,870	1,670
Bushels (1,000)[a]	116	132	146	130
Ten-years' expected life				
Number of estimates	7	3	3	13
Average:				
Years	10	10	10	10
Acres	150	180	170	160
Expected life:				
Acres	1,500	1,800	1,700	1,620
Hours[a]	1,350	1,620	1,530	1,450
Bushels (1,000)[a]	105	126	119	113
All machines				
Number of estimates	11	6	6	23
Expected life:				
Acres	1,560	1,840	1,890	1,720
Hours	1,400	1,660	1,700	1,550
Bushels (1,000)	109	129	133	120

[a] Expected life in hours and bushels was computed on the basis of 109 hours of harvesting time and 70 bushels per acre, respectively.

There was some variation in expected life among the three types of field shellers, but these differences were not significant. Therefore, in computing depreciation, a 10-year obsolescence period or a maximum life of 120,000 bushels, whichever was the limiting factor, was used.

Power units were depreciated on the basis of a 10-year obsolescence period or expected life in bushels or hours of use, whichever was the limiting factor. An expected life of 7,000 hours was used for the conventional tractor and 240,000 bushels for the uni-tractor and sheller engine.

Other fixed costs, in addition to depreciation, were interest at 5 percent of average value — 2.5 percent of original cost; property tax at $0.375 per $100 of new cost; shelter at 0.5 percent and insurance at 0.25 percent of new cost.

The most common power units were the conventional wheeled tractor for the pull-type machine and picker-and-trailing sheller, a mounted gasoline engine for the sheller, and a special purpose uni-tractor for the self-propelled field sheller. Power costs for the tractors were based on data from Illinois detailed cost-account records.[1] Two-thirds of the fixed costs of the uni-tractor and sheller engine were allocated to the corn harvest.[2]

Labor was charged at 90 cents an hour for the operation of the field sheller and for maintenance and repairs.

Repair costs of the field shellers, as reported by farmers, were used in summarizing the farm records (Table 8). Repair costs were higher for the pull-type machines because, as a group, they were older machines.[3] However, repair costs for all types of machines were based on an estimate of total life repairs equal to 30 percent of the original purchase price (Table 11).[4]

Fuel use was the only item of power-operating costs recorded by farmers. In this analysis, fuel costs were used to estimate total operating costs of the power units.[5]

[1] See Appendix Table 30.

[2] Costs of the uni-tractor were allocated on the assumption that farmers owned both picker-sheller and small-grain combine attachments. On the average, corn-belt farm-machine time for small grain harvest is about half the total for corn harvest.

[3] See Appendix Table 29 for average repair costs and ages by type of field sheller.

[4] For recommended annual repair costs of harvesting machinery, see page 4 of "Crop Machinery Use Data," Amer. Soc. Agr. Engin., 1949.

[5] See Appendix Table 30. Illinois detailed cost-account records show that fuel represents 60 percent of total power-operating costs.

Lubrication of the field sheller amounted to about 4 cents per 100 bushels. This estimate was based on a complete lubrication of the machine after each 5 hours of use.

(Appendix E)

METHOD OF COMPUTING FIXED COSTS OF DRYING

Fixed costs were computed from median investment costs of drying equipment as reported by farmers.[1] In most instances, investment in the heating unit and drying structure was not reported separately. Therefore, drier investment cost includes both pieces of equipment.

Other equipment needed for the complete drying operation included a fuel tank, moisture tester, and electrical wiring. The additional wiring and electrical devices to operate the drier and conveying equipment averaged $155 per farm on 36 farms. The total cost of the electrical system was allocated to the drying operation.

Depreciation. Most drying equipment had not been in use long enough to permit determination of life in either years or output. Twenty-five farmers, although limited by experience, estimated length of life for both heating unit and drying structure as follows:

	100 acres and less	*101-200 acres*	*201-300 acres*	*All farms*
Number of farms	6	10	9	25
Average annual bushels of corn dried per farm	6,220	9,930	16,930	11,560
Heating unit				
Expected life:				
Years	9	14	14	13
Bushels	56,000	139,000	237,000	154,000
Drying structure				
Expected life:				
Years	14	17	17	16
Bushels	77,000	169,000	288,000	192,000

Length of life based on size of operation and use did not conform with normal expectations, since expected life increased as use increased. Lack of experience and the numerous types and models of driers and drying structures contributed to these results.

Farmers' estimates indicated a difference between the expected life of the heating unit and that of the drying structure. An expected life

[1] See Appendix Table 31.

of 154,000 bushels or 13 years' obsolescence period was used for the complete heating unit and structure because we were unable to obtain estimates from farmers for the two pieces of equipment. Annual use was so limited that obsolescence was the limiting factor for all groups of driers — except the oil-burning column driers, which had an average annual use large enough to be depreciated in 12 years.

Other fixed costs. Annual fixed costs other than depreciation included interest at 5 percent of average investment — 2.5 percent of original cost; property tax at $0.375 per $100 of new cost; shelter, 0.5 percent of new cost; and insurance, 0.25 percent of new cost.

(Appendix F)
SUPPLEMENTARY TABLES

Table 22. — Total and Tillable Acres on 77 Illinois Survey Farms Compared With the Average for the Area, by Type-of-Farming Area, 1954

	Area 1	Area 2	Area 3	Area 4	All farms
Survey farms					
Number of farms	12	15	11	39	77
Acres					
Total per farm					
Average	613	424	437	417	444
Median	460	280	346	383	380
Range	310–1,040	160–1,200	160–768	160–1,300	160–1,300
Tillable per farm					
Average	489	374	396	370	393
Median	440	243	340	310	310
Range	225–900	140–853	150–673	150–745	140–900
Percent tillable	80	88	91	89	89
Area farms[a]					
Average per farm	136	171	174	186	176
Average tillable per farm	115	148	139	167	154
Percent tillable	85	87	80	90	88

[a]Data from U. S. Census of Agriculture, 1950, vol. 1, part 5, Bureau of Census, pp. 40-47, 1952. Averages for the type-of-farming areas were based on only those counties in which survey farms were represented.

Table 23. — Classification of 77 Illinois Farms Field-Shelling and Drying Corn, by Type-of-Farming Area and Type of Farm, 1954[a]

Type of farm	Area 1	Area 2	Area 3	Area 4	All farms	Percent of all farms
			Number of farms			
Grain	7	6	2	24	39	51
Beef and hog	0	3	7	10	20	26
Dairy	2	4	0	2	8	11
Hog	1	1	1	2	5	6
Beef	1	1	1	1	4	5
Poultry	1	0	0	0	1	1
Total	12	15	11	39	77	100

[a] Classification was based on livestock inventory, acres of crops, and disposition of corn for 1954.

Table 24. — Livestock on 77 Illinois Farms Field-Shelling and Drying Corn, by Type-of-Farming Area, 1954[a]

	Area 1	Area 2	Area 3	Area 4	All farms
Number of farms	12	15	11	39	77
Number of farms with pigs	4	11	9	15	39
Litters per farm					
Average	55	35	71	49	51
Range	40-75	10-80	14-150	6-178	6-178
Number of farms with feeder cattle	6	6	8	17	37
Feeder cattle per farm					
Average	87	73	83	97	89
Range	4-225	51-125	15-273	2-400	2-400
Number of farms with beef cows	3	1	5	9	18
Beef cows per farm					
Average	35	16	25	27	27
Range	2-75	16	5-40	7-67	2-75
Number of farms with dairy cows	6	6	4	18	34
Dairy cows per farm					
Average	23	29	4	12	16
Range	1-80	1-75	1-10	1-41	1-80
Number of farms with hens	7	3	6	18	34
Hens per farm					
Average	1,521	253	292	199	492
Range	25-10,000	160-300	24-1,000	20-700	20-10,000

[a] Other livestock and poultry included sheep, lambs, broilers, ducks, capons, and geese.

Table 25. — Average Total Acres per Farm by Tenure, 77 Illinois Farms Field-Shelling and Drying Corn, 1954

Item	Owner-operated	Part-owner	Manager	Tenant	All farms	Percent of total acres
Number of farms	25	21	3	28	77	...
Acres per farm operated by:						
Owner	432	199	...	...	195	44
Tenant	...	185	...	459	217	49
Manager	...	...	820	...	32	7
Total	432	384	820	459	444	100
Percent of farms	33	27	4	36	100	...
Percent of land operated	32	23	7	38	100	...

Table 26. — Average Acres of Crops on 77 Illinois Farms Field-Shelling and Drying Corn, by Type-of-Farming Area, 1954

Crop	Area 1	Area 2	Area 3	Area 4	All farms
Number of farms	12	15	11	39	77
Corn					
Average acres	242	162	188	174	184
Median acres	250	108	168	140	150
Range in acres	85–425	44–480	75–376	35–835	35–835
Percent of tillable acres	50	43	48	47	47
Wheat					
Average acres	15	3	17	23	17
Range in acres	0–99	0–38	0–83	0–105	0–105
Percent of farms raising wheat	33	13	55	44	38
Percent of tillable acres	3	1	4	6	4
Oats					
Average acres	83	80	60	53	64
Range in acres	0–265	28–194	35–105	0–104	0–265
Percent of farms raising oats	83	100	100	92	94
Percent of tillable acres	17	21	15	14	16
Soybeans					
Average acres	52	51	46	63	57
Range in acres	0–212	0–280	0–190	0–300	0–300
Percent of farms raising soybeans	42	40	73	73	61
Percent of tillable acres	11	14	12	17	14
Hay and pasture					
Average acres	81	78	81	52	65
Range in acres	0–395	12–179	10–253	0–154	0–395
Percent of farms raising hay and pasture	83	100	100	87	91
Percent of tillable acres	16	21	20	14	17
Other crops[a]					
Average acres	16	0	4	5	6
Range in acres	0–80	0	0–50	0–122	0–122
Percent of tillable acres	3	0	1	2	2
Total tillable acres	489	374	396	370	393

[a] Other crops include barley, rye, peas, sweet corn, asparagus, and corn silage.

Table 27. — Disposition of Corn Harvested for Grain on 77 Illinois Farms Field-Shelling and Drying Corn, by Type-of-Farming Area, 1953 and 1954

	Sold			Sealed			Fed			Total		
	1953	1954	Average	1953	1954	Average	1953	1954	Average	1953	1954	Average
Area 1												
Bushels per farm												
Average	3,862	4,594	4,155	5,780	3,490	4,864	5,167	7,587	6,135	14,809	15,671	15,154
Percent	26	29	27	39	22	32	35	49	41	100	100	100
Number of farms	7	5		8	3		9	6		12	8	
Area 2												
Bushels per farm												
Average	7,016	5,378	6,288	1,413	1,658	1,522	3,908	4,995	4,391	12,337	12,031	12,201
Percent	57	45	51	11	14	13	32	41	36	100	100	100
Number of farms	14	9		3	4		14	10		15	12	
Area 3												
Bushels per farm												
Average	4,755	2,829	3,792	2,700	3,802	3,251	5,918	5,116	5,517	13,373	11,747	12,560
Percent	36	24	30	20	32	26	44	44	44	100	100	100
Number of farms	7	5		6	6		11	6		11	11	
Area 4												
Bushels per farm												
Average	5,670	5,529	5,602	3,700	2,666	3,204	4,499	4,314	4,410	13,869	12,509	13,216
Percent	41	44	42	27	21	24	32	35	34	100	100	100
Number of farms	23	24		13	13		27	22		39	36	
Total												
Bushels per farm												
Average	5,520	4,875[a]	5,254	3,436	2,729	3,126	4,691	4,885	4,815	13,647	12,489	13,195
Percent	40	39	40	25	22	24	35	39	36	100	100	100
Number of farms	51	43		30	26		61	44		77	67	

[a] In 1954, an average of 1,300 bushels of corn per farm, or about 10 percent of the total corn crop, was sold at harvest. Twenty-two of the 43 farms reported selling some corn at harvest.

Table 28. — Field Loss Checks of 14 Field Shellers by Time of Day, Illinois, 1954[a]

Machine	Checks	Moisture content	Lodged stalks	Ear drop	Machine loss[b]				Total loss	Gross yield			Gross yield[c]
					Ear	Shelled		Total		Ear drop	Machine	Total	
						Loose	On Cob						
	number	*perct.*	*perct.*	*bu./A.*	*bu./A.*	*bu./A.*	*bu./A.*	*bu./A.*	*bu./A.*	*perct.*	*perct.*	*perct.*	*bu./A.*
Morning													
Average	14	19.6	4.7	1.7	1.7	3.4	0.3	5.4	7.1	2.2	7.0	9.2	77.4
Median	..	19.0	2.6	1.8	1.7	3.3	0.1	4.7	6.2	1.4	6.6	8.3	74
Range	..	16–27	1–28	0–8	0–5	1–9	0–1.6	3–10	3–18	0–7	5–9	5–15	52–117
Afternoon													
Average	14	19.6	4.7	1.6	1.5	2.2	0.1	3.9	5.5	2.1	5.0	7.1	77.4
Median	..	19.0	2.6	1.6	1.5	1.9	.0	3.6	5.6	1.7	4.9	7.4	74
Range	..	16–27	1–28	0–7	0–3	1–5	0–0.8	2–9	2–10	0–7	3–9	3–10	52–117
Total Morning and afternoon													
Average	28	19.6	4.7	1.7	1.6	2.8	0.2	4.6	6.3	2.2	5.9	8.1	77.4
Median	..	19.0	2.6	1.7	1.6	2.6	0.1	4.1	6.0	1.6	5.7	7.8	74
Range	..	16–27	1–28	0–8	0–5	1–9	0–1.6	2–10	2–18	0–7	3–9	3–15	52–117

[a] The 14 field shellers included 11 pull-type machines, 2 picker-and-shellers, and 1 self-propelled machine.

[b] Shelled-corn loss by the machine was greater in the morning on 10 of the 14 farms; ear-corn loss was greater in the morning on 8 of the 14 farms.

[c] Harvested yield equals gross yield minus total bushels' loss. Harvested yield was 70.3 bushels for the morning check and 71.9 for the afternoon.

Table 29. — Summary of Harvesting, Hauling and Unloading Data on 45 Illinois Farms Keeping Daily Records of Field-Shelling and Drying, by Type of Field Sheller, 1954

Item	Pull-type picker-sheller	Self-propelled picker-sheller	Picker and sheller	All field shellers
Number of farms	25	13	7	45
Length of harvest, days[a]				
Average	28.4	27.3	38.7	29.7
Median	26	27	36	27
Range	4–72	11–62	26–56	4–72
Number days harvesting[b]				
Average	16.4	16.8	21.6	17.2
Median	15	15	22	17
Range	3–54	9–37	18–27	3–54
Acres harvested				
Total per farm				
Average	114	108	183	123
Median	94	101	202	102
Range	21–380	45–284	132–218	21–380
Per day[b]				
Average	7.0	6.5	8.5	7.1
Median	6.8	6.7	8.2	6.8
Range	2.8–13.8	3.0–10.8	6.8–10.9	2.8–13.8
Per hour				
Average	1.1	1.2	1.1	1.1
Median	1.1	1.1	1.1	1.1
Range	.7–1.7	.8–2.0	.9–1.4	.7–2.0
Bushels harvested				
Total per farm				
Average	7,380	8,140	14,470	8,700
Median	6,920	7,100	14,720	7,325
Range	1,690–26,610	3,672–23,486	10,886–18,245	1,690–26,610
Per day[b]				
Average	451	485	671	504
Median	493	446	676	542
Range	243–916	295–715	518–831	243–831
Per hour				
Average	70	88	88	78
Median	82	86	95	85
Range	46–131	60–128	73–105	46–131
Per acre				
Average	65	75	79	71
Median	70	77	77	75
Range	49–101	61–101	72–93	49–101
Hours harvesting				
Total per farm				
Average	106	93	165	111
Per 100 bushels				
Average	1.4	1.1	1.1	1.3
Median	1.3	1.2	1.1	1.2
Range	.8–2.2	.8–1.7	1.0–1.4	.8–2.2
Per acre				
Average	.93	.85	.90	.90
Median	.92	.92	.87	.92
Range	.6–1.4	.5–1.3	.7–1.0	.5–1.4
Hours maintenance and repairs				
Total per farm				
Average	17.2	22.2	29.5	20.5
Per 100 bushels				
Average	.23	.27	.20	.24
Median	.19	.22	.23	.21
Range	.07–.82	.10–.56	.10–.28	.07–.82
Field-sheller repairs				
Total per machine				
Average	$ 53.73	$ 31.77	$ 48.67	$ 46.60
Median	54.00	19.06	49.73	35.37
Range	$.80–148.30	$1.80–115.71	$8.00–95.48	$.80–148.30

(Table is concluded on next page)

Table 29. — Concluded

Item	Pull-type picker-sheller	Self-propelled picker-sheller	Picker and sheller	All field shellers
Age of field shellers, years				
Average	4.7	2.0	2.0	3.5
Median	4.5	2.0	2.0	3.0
Range	1–15	1–3	1–3	1–15
Gasoline used by tractors, gallons				
Total per machine				
Average	235	206	329 (216)[c]	241
Per 100 bushels				
Average	3.2	2.5	2.3 (1.5)	2.8
Median	2.9	2.6	2.3 (1.4)	2.7
Range	1.2–4.1	2.0–3.0	1.6–3.2	1.2–4.1
Per acre				
Average	2.1	1.9	1.8 (1.2)	2.0
Median	2.0	1.9	1.8 (1.1)	2.0
Range	1.0–3.4	1.5–2.5	1.5–2.4	1.0–2.4
Man-hours hauling and unloading				
Total per farm				
Average	60	74	148	78
Per 100 bushels				
Average	.82	.91	1.02	.89
Median	.68	.66	1.01	.74
Range	.29–1.74	.26–2.48	.90–1.10	.26–2.48
Estimated total bushels' machine loss				
Number of farms	20	10	4	34
Per acre				
Average	4.8	4.8	5.6	4.9
Median	4.5	4.2	5.6	4.3
Range	2.2–8.1	1.5–10.0	4.0–7.4	1.5–10.0
Percent of total yield				
Average	5.9	5.2	5.8	5.6
Median	6.3	4.9	5.6	5.2
Range	2.6–9.6	1.7–11.0	4.6–8.0	1.7–11.0

[a] Number of days from beginning to end of harvest season.
[b] Number of days on which harvesting was performed with no specified number of hours.
[c] Figures in parentheses are for the sheller.

Table 30. — Average Tractor Costs by Drawbar Horsepower Ratings, Illinois, Sangamon Area, 1952, and Lincoln Area, 1953[a]

	10.0 through 20.9 hp.			21.0 through 33.0 hp.			Average of all tractors
	1952	1953	Average	1952	1953	Average	1952-53
Number of tractors	39	50	89	40	39	79	168
Average drawbar horsepower	18.1	17.4	17.7	26.7	27.1	26.9	22.0
Hours tractors were used	441	489	468	596	577	587	524
Average total cost per hour of use	$.92	$1.02	$.97	$1.19	$1.31	$1.25	$1.11
Operating cost	.54	.64	.59	.66	.81	.73	.66
Fixed cost	.38	.38	.38	.53	.50	.52	.45
Operating cost as a percentage of total operating costs							
Fuel	56	61	59	56	64	60	59
Oil and grease	8	8	8	8	9	8	8
Repairs	30	27	28	32	25	29	29
Labor	6	4	5	4	2	3	4
Total	100	100	100	100	100	100	100

[a] Detailed cost reports for central Illinois, 1952, and for southern Illinois, 1953. Department of Agricultural Economics, University of Illinois, November, 1953, and December, 1954.

Table 31. — Summary of Drying Data of 43 Heated-Air Drying Units, by Type of Fuel and Drying Structure, Illinois, 1954

Item	Type of fuel and drier			
	LP, column	Oil, column	Oil, bin	Oil, wagon
Number of driers	8	25	7	3
Investment, drier				
Average	$ 3,330	$ 3,510	$ 2,910	$ 2,530
Median	3,440	3,270	3,050	2,600
Range	$3,000–4,200	$2,050–5,600	$2,450–4,150	$2,150–2,850
Corn, dried				
Acres	135	133	107	74
Bushels (wet)[a]	11,890	10,870	8,175	7,230
Bushels (dry)[a]	10,430	9,650	7,270	6,640
Water removed, pounds				
Per farm[b]	81,770	68,210	50,790	33,150
Per bushel (dry)[b]	7.8	7.1	7.0	5.0
Per gallon of fuel	50	46	50	38
Per machine-hour	556	325	319	235
Machine use, hours				
Per drier	147	210	159	141
Per 100 bushels (dry)	1.4	2.2	2.2	2.1
Per 1,000 pounds water				
Average	1.8	3.1	3.1	4.2
Median	1.7	2.7	3.1	3.9
Range	1.3–2.6	2.4–4.2	1.0–6.1	3.7–5.3
Man-hours				
Per drier	54	42	25	34
Per 100 bushels (dry)	.52	.39	.34	.51
Per 1,000 pounds water				
Average	.7	.6	.5	1.0
Median	.7	.7	.5	.8
Range	.2–1.2	.3–1.9	.4–.6	.4–1.5
Fuel, gallons				
Per drier	1,618	1,471	1,007	873
Per 1,000 pounds water				
Average	19.8	21.6	19.8	26.3
Median	20.7	23.7	15.4	26.8
Range	13.2–31.8	11.8–40.3	8.6–34.1	23.1–27.9
Per machine hour	11.0	7.0	6.3	6.2
Size of batch, bushels of dry corn				
Average	263	212	546	138
Median	300	220	540	130
Range	150–320	100–425	430–650	100–190
Drying temperature, degrees F.				
Average	160	150	140	145
Median	150	150	145	140
Range	140–180	120–190	120–150	135–160
Number 130 degrees F. and below	0	4	2	0
Age, years	2.0	2.9	4.4	3.0
Makes of drying structures				
Commercial	2	9	1	0
Farm-built	1	4	0	3
Drying structures with overhead storage	2	19	0	0
Horsepower-hours per hour use of drier	7.5	6	5	5

[a] All bushels reported were assumed to weigh 56 pounds per bushel regardless of moisture content.

[b] Pounds of water removed = number of wet bushels × 56 pounds per bushel × $\left(1 - \frac{100 - \text{Beginning moisture content}}{100 - \text{Ending moisture content}}\right)$.

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